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JOURNAL OF PALEONTOLOGY

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VOLUME 24 | MARCH, 1950 | NUMBER 2

SYMPOSIUM AND ROUND-TABLE CONFERENCE ON FUNDAMENTALS IN PALEONTOLOGY AT THE ST. LOUIS MEETING OF THE S.E.P.M. IN 1949

INTRODUCTION

IN THE course of preliminary discussions of the program for the St. Louis meeting of the S.E.P.M. (1949) the idea of a symposium on fundamentals in paleontology was conceived. Dr. Maynard P. White, the chairman of the program committee, invited several interested paleontologists to participate and thus a group of speakers was secured. Dr. George E. Condra agreed to serve as chairman of the symposium and moderator of the subsequent round-table conference. To him and to Dr. Maxim K. Elias was also entrusted the duty of securing the manuscripts from the participants of the symposium and the conference.

Following is the program of the Symposium:

Introduction, by G. E. Condra
A fusulinid slide rule, by M. P. White
The role of Paleozoic ammonoids in pure and applied geology, by A. K. Miller
Rates of evolution and measurement of geologic time, by L. L. Sloss
Phylogeny and stratigraphy, by R. H. Flower
The state of paleontology, by M. K. Elias
Informal discussion, by H. B. Stenzel
Informal discussion, by N. D. Newell
Summary and suggestions, by G. E. Condra

Thanks to the interest of many leading paleontologists and stratigraphers the symposium and the conference were well attended, and under the direction of Dr. Condra an important discussion concerning fundamental issues in paleontology developed.

The following members of the A.A.P.G. and S.E.P.M. took part in the discussion:

Kenneth E. Caster, Monroe G. Cheney, G. E. Condra, M. K. Elias, R. H. Flower, J. J. Galloway, C. R. McKnight, Lowell R. Laudon, A. K. Miller, Raymond C. Moore, Betty Nadeau (Kellett), N. D. Newell, J. W. Skinner, L. L. Sloss, H. B. Stenzel, Marcus L. Thompson, Charles W. Tomlinson, J. Marvin Weller, and M. P. White.

The discussions which were started at the symposium in the morning continued at the round-table conference in the afternoon. Informal presentations by Dr. H. B. Stenzel and Dr. N. D. Newell were made, and they were discussed by A. K. Miller, K. E. Caster, G. E. Condra, J. M. Weller, M. P. White, M. K. Elias, and others. The manner of indicating some phases in the evolution of major groups of fossil organisms by graphic curves was the subject of detailed discussion between H. B. Stenzel and L. L. Sloss.

The importance of cooperation in paleontological research was stressed by Condra. The participants agreed with him, and it was pointed out that attempts to sponsor such cooperation have been made in the past through a special committee of the A.A.P.G.

Dr. A. L. Lugn emphasized the advisability of organized preservation of core records for the purpose of further research in both paleontology and sedimentology. Elias discussed the meaning of interruptions in the evolutionary lineages reported by Stenzel, and he suggested caution in applying genetic terms to the various apparent changes in fossil populations.

Following are the introduction and the concluding remarks by the chairman, Dr. G. E. Condra, Nebraska Geological Survey.

"Paleontology covers a wide field of activity and service. It functions in well planned field surveys, technical laboratory studies, applied science and higher education. The subject covers more than the collection, study, and classification of fossils and the biologic origin of limestone, soil, peat, coal and petroleum. It involves the evolution of plant and animal life as evidenced in the many geologic formations deposited during long periods of time, and more than any other science, reveals a knowledge of how the varied and changing environment influenced the development of life and the natural use capabilities of present-day plants and animals, such as the grasses, trees, fish, birds, and so-called farm animals. A knowledge of the how-come or evolution of these forms of life is a valuable factual background of general biology, botany, zoology, ecology and plant and animal breeding. Paleontology is a comprehensive subject closely and fundamentally related to stratigraphic, historical and technical phases of applied geology. Textbooks present only an approach to paleontology, whereas well planned systematic surveys and research in the field and detailed laboratory investigations are the underlying fundamental approaches to the science of paleontology. The following discussion is devoted to fundamentals in paleontologic research, the papers being prepared by persons who have made valuable contributions in this field."

At the end of the conference he expressed regret that "time limitations permitted only partial coverage of some of the most important aspects of the organization of paleontological research which were intended for discussion. Paleontology is at the core of stratigraphy and correlation, which are fundamental in petroleum geology. It is the foundation on which historical geology is built, and a framework for the understanding and classification of the geology of the whole earth.

"An adequate, reasonably complete and useful paleontological record can only be reconstructed through joint research by government institutions, universities, and the laboratories of the petroleum industry. Further progress in paleontology, the scientific and utilitarian aspects of which are inseparable, depends on closer cooperation of research paleontologists, and it should be our aim to provide for integration of their individual efforts. The petroleum industry has aided immensely in accumulating accurate paleontological information, and it has produced some of our best paleontologists. Some state geological surveys have contributed importantly to the fundamentals of paleontology, but unfortunately the importance of this phase of their activities has not been universally recognized. Federal institutions should restore closer cooperation in paleontological research with state, university and industrial paleontologists. This symposium and round-table conference were steps toward closer cooperation between research paleontologists and they should be followed by further action in the immediate future. The American Association of Petroleum Geologists, and the petroleum industry, which it represents, has always appreciated the role of paleontology in petroleum geology, and should continue and strengthen its support of organized research in this field."

JOURNAL OF PALEONTOLOGY, VOL. 24, NO. 2, PP. 123–129, PLS. 24, 25, 20 FIGS., MARCH 1950

A FUSULINID SLIDE RULE

M. P. WHITE
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ABSTRACT—An application of the natural laws of evolution, as shown by changes in wall structure and composition, arrangement of chambers, form of test, etc., considered in the order of their importance, points to a simple logical scheme covering the development of the fusulinids. It not only serves to indicate the stratigraphic position of any specimen but it also affords a check on the propriety with which a name is applied to it and prevents disturbing errors which have confused and retarded an understanding of these fossils. It is explained without the use of technical or morphologic terms or taxonomic names, in the belief that it is best understood when freed from such sources of possible confusion.

INTRODUCTION

The philosophic conception of an ever-present urge towards perfection in the structural investments of an organism for the necessary functions they serve in its life, associated with the principle of economy of accomplishment, affords great aid in the solution of paleontological problems and the much neglected theory of recapitulation supplies a proven basis for it.

An easily followed plan for the fusulinids can be constructed, which serves as a close guide to evolutionary development, and thus to the stratigraphic position of any specimen, no matter under what name or names we care to classify it. It emphasizes the relation of the individual to the entire group by treating each morphologic feature in the order of its importance. Thus the emphasis is placed upon proven morphologic progress rather than on unevaluated differentiation.

In such a plan we can recognize progressive development from the nautiloid planispiral with incompletely embracing to completely embracing chambers, with retention of the ancestral or planispiral beginning in the early stage, to a form in which, though the planispiral portion may still be retained, the axis of coiling becomes the greatest dimension for the first time, on to a similar form which has lost the planispiral stage, to that in which the height of volution suddenly increases, giving the appearance of a tightly coiled early stage, or a form which becomes uncoiled, or one in which the chambers are subdivided into chamberlets.

Of even greater importance is the change from a four-, to a three-, a two-, and finally a one-layered wall, together with the relative proportions of the layers. The nature of the tubes which establish the necessary perforate character of the wall, their growth, extent, and even fusion are equally significant.

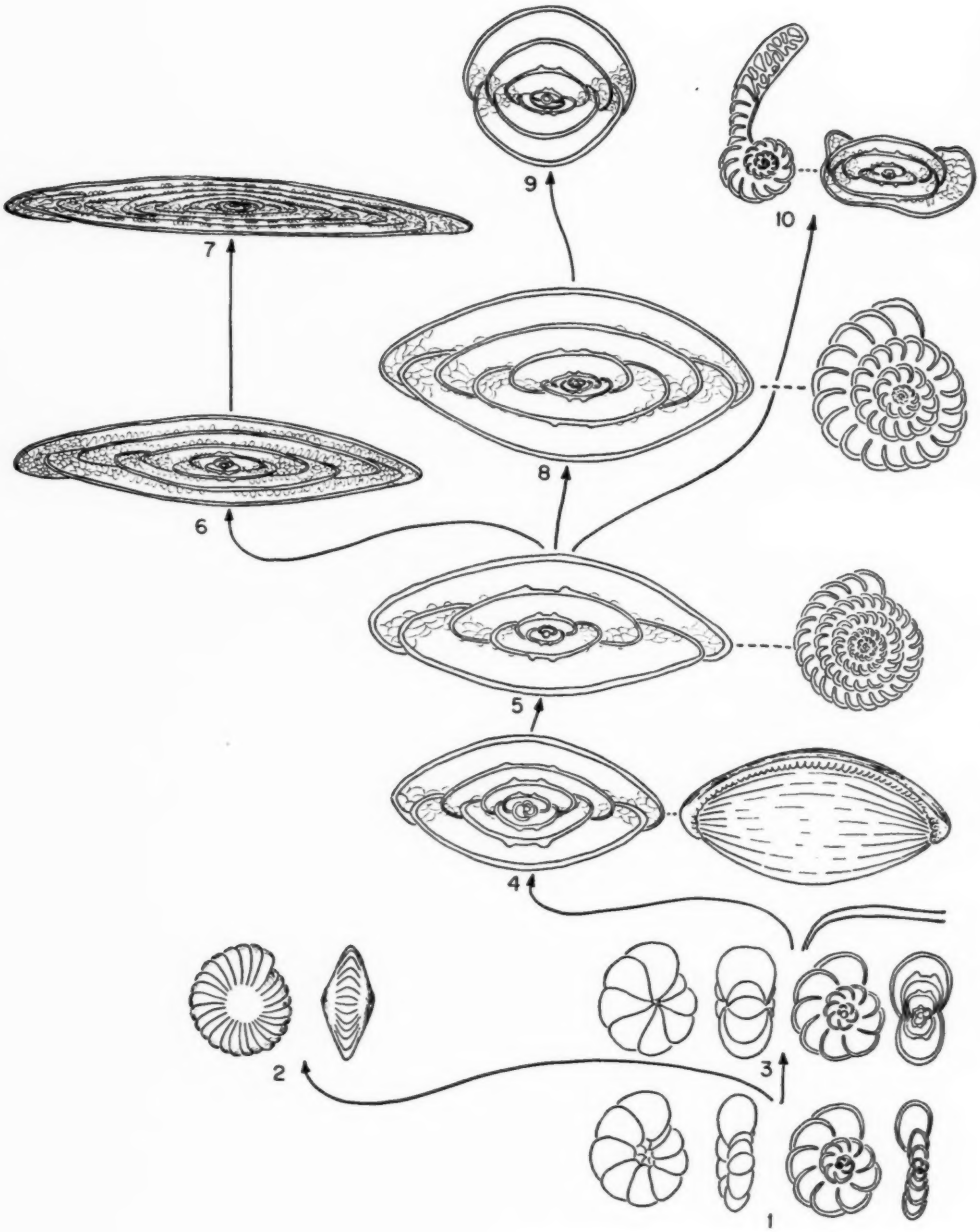
We observe without surprise the tendency of the more primitive forms to outrange the more specialized. We distinguish the more complete recapitulation in microspheric individuals and recognize and understand the nature of secondary filling.

These simple expressions of development present in few words the factors that are essential to an understanding of the fusulinids. If proper attention had been devoted to them, most of the glaring mistakes regarding fusulinid development that have crept into the literature could have been avoided because they have to do with those character changes which are nonrecurrent.

THE PLAN

The simple, idealized sketches shown by text figures 1–20 diagram the plan.

The four views of figure 1 represent the ancestral form, which outranges all its derivatives. Figure 2 represents the completely embracing form with a sharp periphery. Figure 3 shows the form from which all the later ones may have been derived. It possesses a rounded periphery but still retains the planispiral begining. Like the preceding, it outranges most of the later forms. Figure 4 is the first in which the axis be-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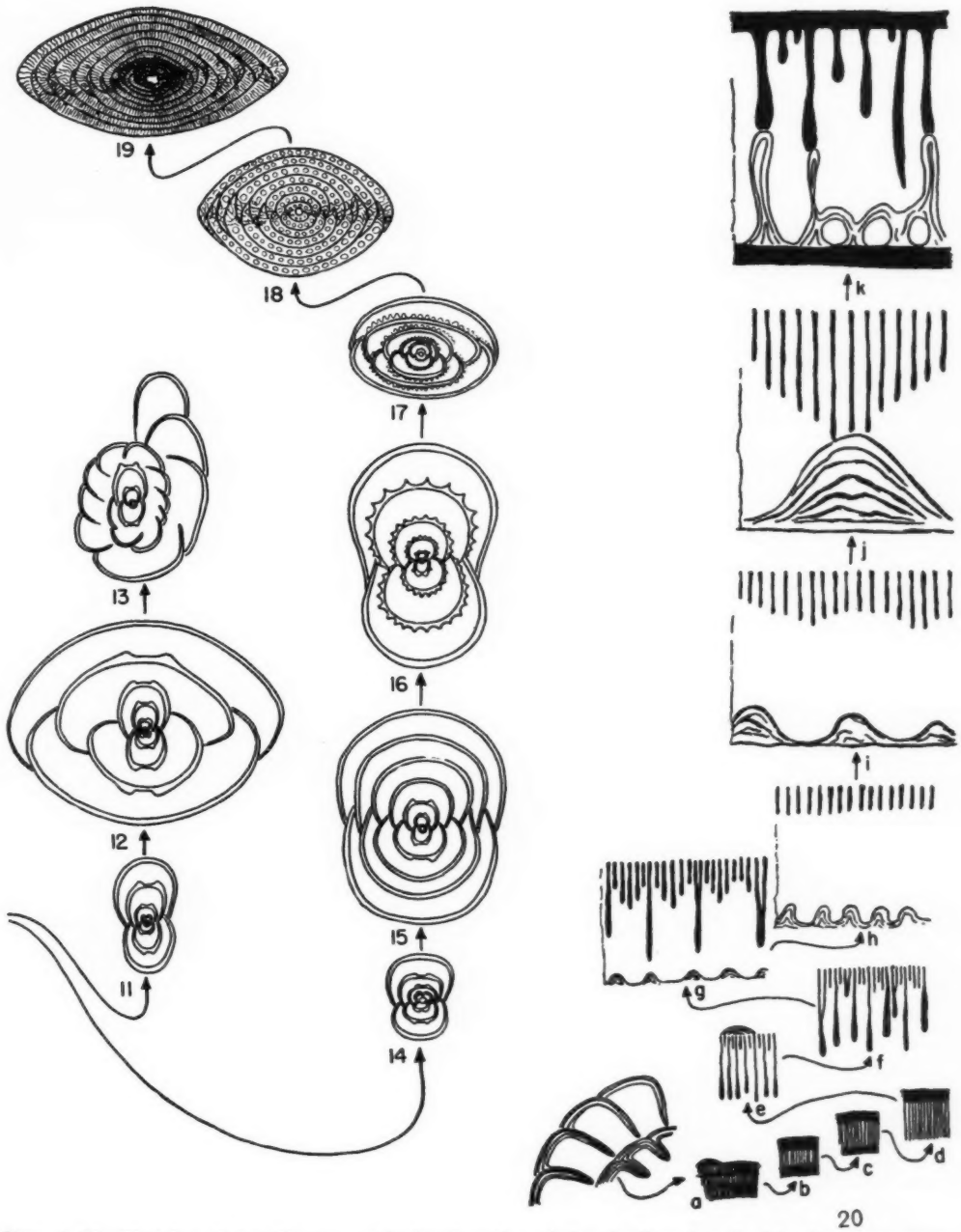


FIGS. *1–20*—Sketches giving diagrammatic "explanation of the plan" as described in the accompanying text.

comes the greatest dimension. It still retains the planispiral early stage and has a considerable range. Figure 5 differs only in the loss of the planispiral stage. From it develop such large, greatly elongated, highly fluted forms as are depicted in figures 6 and 7. The latter has multiple openings between the chambers. The intense fluting of the walls gave rise to the mistaken belief that its chambers are subdivided into chamberlets.

From forms like that of figure 5 were developed those shown by figures 8 and 9, whose chief distinguishing characteristic is a sudden increase in the height of volution, giving the appearance of a tightly coiled beginning. These tend to obesity, and height and breadth become almost equal.

From forms like that of figure 5 also arose those illustrated by figure 10, as a result of uncoiling in the later stages.

From primitive forms like those shown in figure 3 developed a line of forms represented by figures 11, 12 and 13, first by the loss of the planispiral beginning, next by the lengthening of the axis, and finally by late uncoiling. All these retain the stage depicted by figure 11, and none has conspicuously fluted walls.

The form represented by figure 3 also produced a third line. This starts with figure 14, which differs by the loss of the early planispiral stage coupled with a tendency to broaden. This type lost the secondarily deposited material derived from resorptions of the walls which produced the openings between chambers as shown in figure 15. Secondary deposits reappeared in the form depicted by figure 16, but here it produced a series of small ridges on the floor of the spiral wall. The form illustrated by figure 17 differs in its shape. In its late stages the axis is the long dimension and it resembles forms in other lines which assumed a similar shape much earlier. Figure 18 shows a form in which extensions from the upper wall meet those from the floor, thus dividing the chambers into chamberlets. This form also has lost the early stage in which the height exceeded the length of the axis. Figure 19 depicts a final stage, and represents a fusulinid with external apertures and an imperforate wall. These characters, not shared by other fusulinids, direct attention to the much more important portion of the plan which deals with wall structure.

The lettered sketches of figure 20 show the development of the various types of fusulinid wall. *a* represents the typical, primitive wall of four subequal layers. The tubes which perforate it are parallel and penetrate the secondary deposit derived from resorption which produced the openings between chambers. *b* shows a wall of four divisions, but the two outer ones are reduced in thickness relative to the layer next below. The term relative is necessary because there is a tendency for the wall as a whole to grow ever thicker as evolution produced individuals of progressively increasing size. Almost simultaneous disappearance of the two outer layers produced the wall shown in *c* with three divisions, because one of these outer layers actually disappears before the other. *d* shows the next stage, with but two divisions to the wall, which is still perforated by parallel tubes. *e* represents the stage in which the tubes do not extend completely through both layers and in which the walls of the lower portions of the tubes tend to thicken, probably because of the addition of secondarily deposited material. In such a wall the tubes do not extend through the secondary deposit laid down on the floor of the overlying chamber. Further disintegration of the lower layer produced the wall shown in *f*, in which thickening of the tube walls suggests probable fusion of some of these structures. *g* illustrates the wall in which little remains of the lower layer and in which secondary material deposited on the floor of the chamber becomes a characteristic feature. *h* shows the increasing importance of the floor ridges and a simple one-layered wall, which might be mistaken for reversion to a primitive condition, but is not. *i* shows the beginning of differentiation in the single layered wall together with increased growth of the floor ridges. These developments continue until the tubes of the wall and the ridges of the floor join and subdivide the chambers into chamberlets, as in *j*. The final stage is illustrated by *k* where the floor ridges and the remnants of the former wall tubes show the results of continued alteration and the latter are capped by a thin imperforate cover. The

development of this type of wall was necessarily accompanied by the opening of multiple external apertures.

APPLICATION TO FUSULINID PROBLEMS

The first and greatest difficulty which arose in the study of the fusulinids resulted from failure to establish the detailed composition of the wall. Although the wall is obviously calcareous, the most popular textbook devoted to the Foraminifera, which has gone through several editions, continues to list the fusulinids as arenaceous in the key and as calcareous in the text. Even if corrected, error would still exist in that text as it considers *Endothyra*, the ancestral form, as arenaceous, although the remainder of the Fusulinidae are properly listed as calcareous.

This is not a simple slip caused by failure to relate an individual genus to this family. The original generic description of *Codonofusiella* is in part as follows: "It most nearly resembles *Fusiella*, with which it agrees in having an endothyroid juvenarium, in having a very thin wall of two layers," etc. Compare this with part of the generic description of *Fusiella* from the same book: "the wall lacks a recognizable diaphanotheca, consisting of tectum and thin tectoria"; in other words, the wall consists of three layers, not of two. It does recognize the possibility of a four-layered wall simply because it does fail to recognize the diaphanotheca; or what is more likely, to separate it from the tectum.

Belief in the existence of an external aperture, occasioned by the presence of chomata or material deposited at the sides of the openings between chambers, tended to permit continued belief in an arenaceous test. The absence of any external aperture in all but the most advanced variant among the fusulinids, however, is definitely proved by the fact that the antitheca extends completely down to the surface of the underlying whorl where the aperture should be indicated in the drawing to the left of figure 20-*a*. The test must be perforate, and therefore calcareous, because no form can be imperforate and lack an external aperture or apertures.

It is true that the tubes perforating the wall were noted in the more advanced forms where their greater size made them more evident. However, they were not recognized as tubes and they were named alveoli, from *alveolus*, which means a hollow vessel, and all vessels must have bottoms. The tectum was considered to be the impervious layer that formed the bottom of the vessels, which is just what the term implies. Thus both terms should be discarded for the sake of clarity, because the so-called tectum is never impervious or nonperforate, excepting in the most advanced type of wall shown in figure 20-*k*.

The beautifully silicified primitive forms from the Marble Falls limestone obviously possess the tubes, and they were mistakenly identified as *Triticites*, not as *Fusulina*. This confusion continues to the present day, and much Russian, Austrian, Japanese and other literature records the occurrence of *Triticites* stratigraphically below *Fusulina*. This was the real basis for confusion regarding the proper identity of *Fusulina* itself. For a long time both Cisco and Moscovian forms were referred to this genus.

Although a four-layered wall was noted in *Fusulinella*, this genus also was improperly understood because it was not recognized to possess tubes. Other forms were confused with *Fusulinella*, as witness its being listed from both early Pennsylvanian and Permian beds in many regions. This resulted from failure to correctly identify secondarily deposited material on both sides of the two-layered wall of the Permian forms. These can be separated from *Fusulinella* by noting that the tubes of the wall penetrate only the two inner layers, whereas they penetrate all four layers in the early Pennsylvanian genus. I have checked this by studying misnamed Permian specimens from Russia, and a similar check has been made by Austrian workers on misnamed specimens from their country. I have little doubt that this confusion explains reported occurrences in China.

Fusiella has been subject to similar confusion, which resulted from failure to recognize the so-called tectum, or to differentiate it from the diaphanotheca in this early thin walled form, only three of whose wall layers were distinguished. Most of the original figures of Lee and Chen (1930, pl. VI, figs. 1–8) do not show these layers clearly, but their figure 1 of plate 2 (the same specimen

as shown in their figure 1 of plate 6, although this figure is not listed under the species) does because of its greater magnification and clarity. The layers can be seen in the figures of the first American forms described under this name, but the structure was improperly interpreted. A correct understanding of the wall structure of this form makes clear that the evolutionary development of the wall was from four to three to two to one layer, not from three to four to two to one as previously supposed.

Axially elongated primitive fusulinids which retain the planispiral beginning have often been confused with microspheric individuals of many of the more advanced forms. This is because the microspheric individual's chief distinguishing characteristic is the perfection of its recapture of its oldest recognizable ancestral planispiral stage. The figures of plate 24 show, however, that there is no need for such confusion. Besides recapturing the planispiral stage, a microspheric individual, as the name implies, possesses a microsphere as a proloculum which should not be mistaken for the larger megalosphere of a megalospheric individual. In illustrating these differences I present on plate 24 both pencil sketches and actual microphotographs. Such dual representation is necessary because each type of illustration has its obvious advantages and disadvantages.

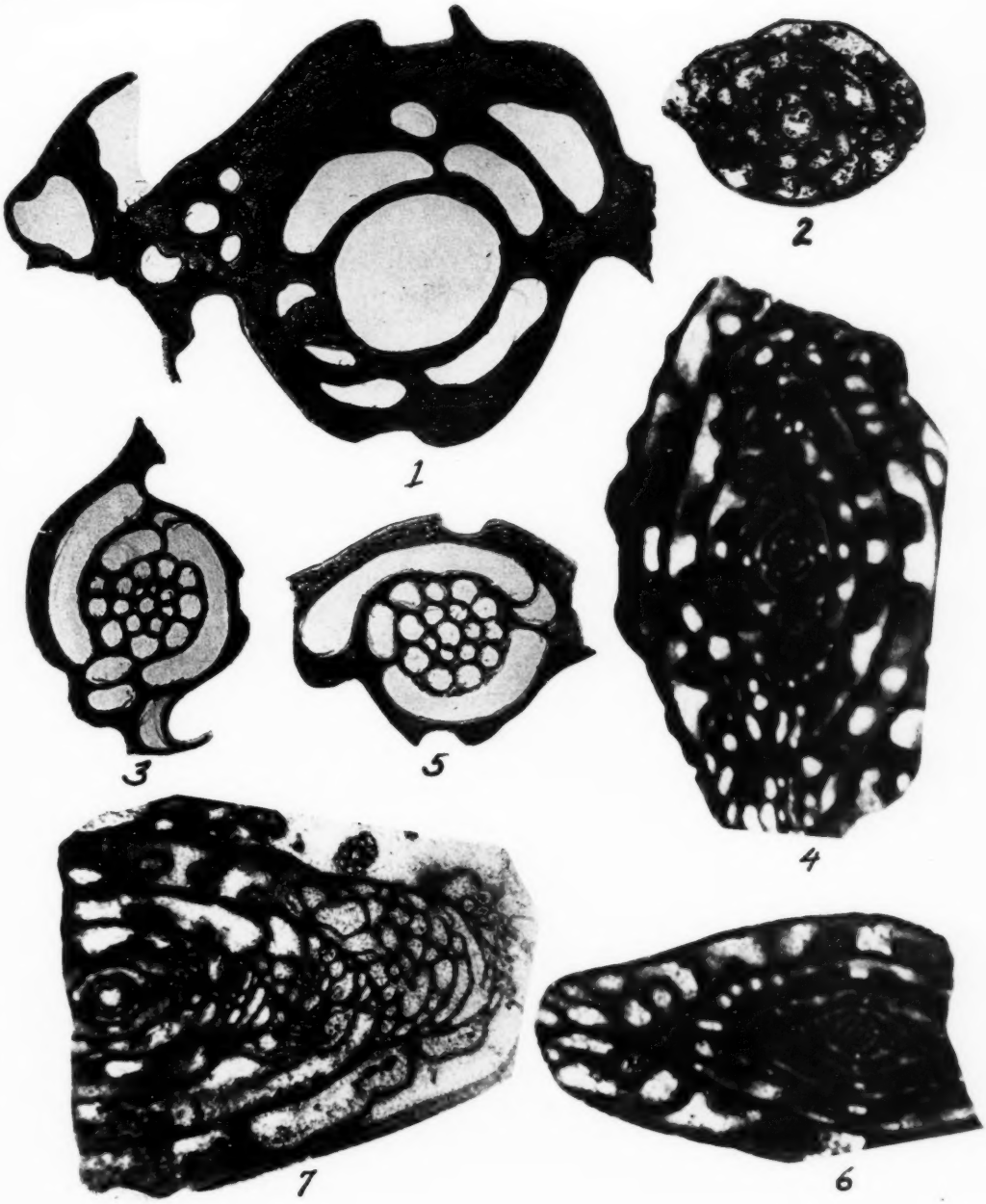
Plate 25 shows microphotographs of the four-layered wall of a very primitive fusulinid and the two-layered wall of a much more advanced form. These clearly show that although such features are not as easily observed as one might wish, or as idealized sketches might lead one to expect, they are unmistakably present. Note, for example, the obvious division of the walls, although this is not too sharply defined nor everywhere apparent. Note the parallel tubes passing through all layers including the depositional material in the more primitive form. Note their failure to always pass through both layers, and their failure to extend through depositional material in the more advanced two-layered form. In this two-layered form note also the fusion of some tubes and the thickening of many tube walls. For proper understanding, such features must be sought and studied where preservation is most perfect. They cannot be determined in all parts of the illustrations which were made, not of average specimens, but from unusually good ones. This fact lends weight to the suggestion made by Drs. Gustava and Franz Kahler that workers refrain from basing genera or species on specimens whose walls are not adequately preserved.

CONCLUSIONS

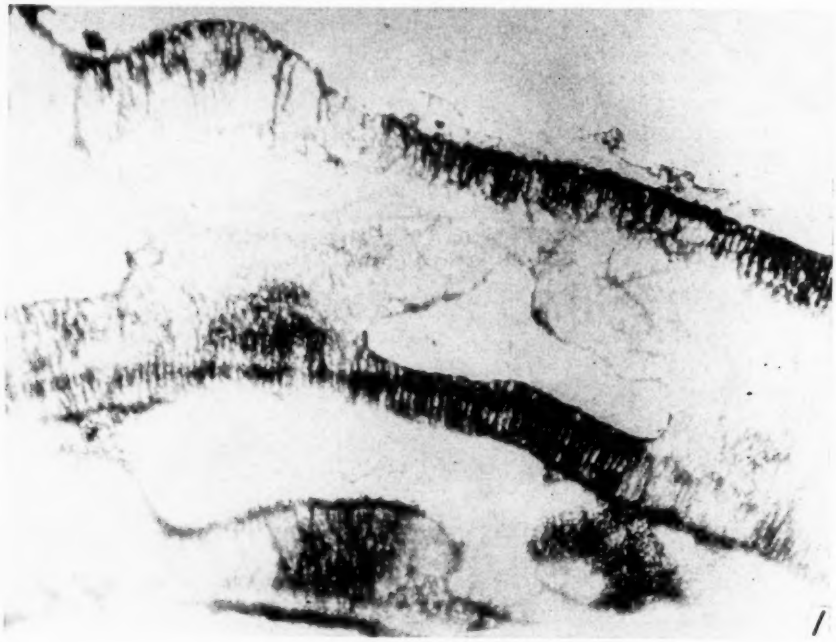
This paper is not an exhaustive attempt to explain the morphology of fusulinids, but it calls attention to the fundamentals which, if carefully observed, will prevent continuation or recurrence of confusing errors. It barely mentions such variations as shape, form, filling, fluting, etc. In my own work I use transparent colored graphs showing ten or more such measureable characters which, by superimposing, make close differentiation possible, but these comparisons are made only after grouping on the basis of the more fundamental characters. I have found that averages are both significant and surprisingly constant, in marked contrast to the variable nature of measurements made on either side of the proloculum of a single individual. This method suggests my title, "A fusulinid slide rule."

EXPLANATION OF PLATE 24

FIG. *1*—Camera lucida pencil sketch of the beginning stage of *Schubertella*, ×210. (p. 128)
2—Microphotograph of the same specimen, ×44. (p. 128)
3—Camera lucida pencil sketch of the beginning stage of a microspheric form of *Fusulina*, ×210. (p. 128)
4—Microphotograph of the same specimen, ×47. (p. 128)
5—Camera lucida pencil sketch of the beginning stage of a microspheric form of *Triticites*, ×210. (p. 128)
6—Microphotograph of the same specimen, ×36. (p. 128)
7—Microphotograph of longitudinal section of a megalospheric specimen of *Triticites* in the seventh or last whorl of which can be seen a microspheric embryo, ×41. (p. 128)



White, Fusulinid Slide Rule



White, Fusulinid Slide Rule

Text figure 5 shows specimens having a shape not attained in another line until a much later time (compare figure 19). The former may still possess a four-layer wall, while the wall of the latter consists of a single layer which is imperforate. These similarities and differences indicate that when we seek to determine the position of specimens in the evolutionary scale, and thereby estimate their stratigraphic position, this must be calculated, just as on the slide rule, by comparing differently weighted characters with each other.

Any simple evolutionary progression, such as that outlined here, is not infallible. Minor variations and exceptions occur, resulting from unusual development of secondary characters. Such exceptions do not, however, detract from the value of the fundamental controlling plan, expecially if the causes of the exceptions are noted and evaluated. In this connection mention need be made only of the difficulties occasioned by dwarf specimens, especially in regard to the comparison of measurements.

ACKNOWLEDGMENTS

I am duly grateful to the host of workers whose publications have permitted me to become familiar with forms never available for my personal observation; to the Gulf Oil Corporation in whose service my work has been carried on, and whose permission makes this publication possible; and to Dr. Maxim K. Elias, whose encouragement and direct assistance in preparing the plates induced me to carry it to completion.

REFERENCE

LEE, J. S., CHEN, S., and CHU, S., The Hanglung limestone and its fauna: Chinese Nat. Research Inst. Geol. Mem. no. 9, pp. 107–109

EXPLANATION OF PLATE 25

FIG. *1*—Microphotograph of *Fusulina*, ×200. (p. 128)
2—Microphotograph of *Triticites*, ×200. (p. 128)

JOURNAL OF PALEONTOLOGY, VOL. 24, NO. 2, P. 130, MARCH 1950

THE ROLE OF PALEOZOIC AMMONOIDS IN PURE AND APPLIED GEOLOGY

(ABSTRACT)

A. K. MILLER
State University of Iowa

The value of ammonoids as index fossils is well known. Although the scope of genera is being progressively narrowed, new material is continually being collected and described, and many of the restricted genera are proving to be of almost world wide distribution. Few Paleozoic forms have, however, been found in South America. Fairly recently, several characteristic Upper Pennsylvanian American genera (for example, *Uddenites*) have been reported from the southern Urals, suggesting that the evolution of the complicated ammonoids of the Permian from the relatively simple types of the Carboniferous may not have taken place exclusively in the region that is now southwestern United States, as has been generally believed.

Occasionally, recognizable portions of large specimens have been found in well cores, and many small individuals are encountered in various types of subsurface samples. The majority of the latter seem to represent only the immature portions of the conch, and we do not as yet know how to identify most of them with a reasonable degree of certainty. However, a few species never attained large size, and they can be used to good advantage in subsurface work. Small mature specimens can be differentiated from equal-sized immature individuals by the fact that in the former the adoral sutures are closely spaced and each is essentially a duplicate of the one that precedes it.

JOURNAL OF PALEONTOLOGY, VOL. 24, NO. 2, PP. 131–139, 8 TEXT FIGS., MARCH 1950

RATES OF EVOLUTION

L. L. SLOSS
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ABSTRACT—Figures on the number of species recorded in various categories of marine invertebrates may be plotted against computed points on the geologic time scale to produce curves which illustrate the frequency distribution of species in time. Investigation indicates that the frequency distribution patterns of a number of groups of animals for which sufficient data are available are represented by symmetrical probability curves. The symmetry of the curves suggests a number of theoretical considerations in terms of rates of speciation and extinction, longevity of species, and the relationship between physical and biologic change.

INTRODUCTION

Charles Lyell appears to have been among the first to recognize the significance of quantitative data as applied to the distribution of organisms in the time dimension. His subdivision of the Tertiary according to the percentage of modern forms represented at its various parts remains a classical example with useful connotations in present day thought on paleontology and biology. In contrast to the wealth of data and principles pertaining to modern animals and plants developed in the fields of experimental and applied genetics, for instance, relatively little quantitative data and relatively few analytical concepts pertaining to the time-distribution of organisms have emerged from the paleontologic studies of the past several decades. This lack is made understandable by consideration of major deterrents inherent in paleontologic data which serve to inhibit quantitative approaches and analyses.

Among primary bases for studies of the distribution of organisms in time are the recognition of the degree of differentiation or diversification expressed by various taxonomic groups in successive intervals of geologic time, and the measurement of the life-span of such groups and their subdivisions. With the increasing accuracy of radioactive age determinations, the dating of specific moments in geologic time and measurement of the duration of such major fractions of time as periods can be reasonably well established. However, determinations of degree of differentiation, as expressed by the number of species in an order or the number of genera in a class, are affected by the state of systematic taxonomy and the stage to which collection and study of any group has been carried.

Taxonomic problems are, perhaps, the most fundamental obstacles to the quantitative approach. There is little agreement among paleontologists as to what constitutes a fossil species, and even less unanimity of opinion on the definition of the higher categories. Therefore, calculations based on such data as the number of species of a certain order recognized in a certain period of time may be more affected by "lumping" or "splitting" than by actual biologic patterns. Nevertheless, it is not entirely unreasonable to assume that the number of taxonomic units recognized in a given group for a given interval of geologic time is some measure of the degree of differentiation. All paleontologists would agree that the trilobites were more varied in the Ordovician than in the Pennsylvanian and that the relative difference is partially expressed by the number of genera recognized in the two periods. In other words, figures on the number of species, genera, etc., may, in many instances, be accepted as valid relative data, but there is abundant room for argument as to the validity of quantitative manipulations of such data.

Other objections to quantification are raised by the incomplete state of paleontologic knowledge. Each year thousands of new species are described as new collections are made and old collections restudied. It seems statistically sound, however, to assume that the data accumulated to date

represent a fair sample of the distribution pattern which will emerge on Judgment Day, when the last genus will have been defined and the last species named.

Paleontologic data are also influenced by variations in the attention devoted to various areas and various portions of the stratigraphic column because of economic pressure, availability of fossiliferous exposures and other factors. The effect of these inequalities is somewhat diminished if sufficiently large areas are encompassed, thus submerging the influence of any strictly local factors. Figures on crinoids, for instance, are faulty if only North American data are employed with exclusion of Devonian and Permian material from Europe and the eastern Tethyan areas.

In the face of these obstacles to numerical analysis several interesting and significant studies have appeared in the past few years. Examples are found in the treatment of fossil vertebrates by Simpson (1944), and of paleobotanical material by Small (1937, 1938). More recently, the problem of evolutionary rates has been reviewed by Zeuner (1946) and was the subject of discussion by a number of authorities during the Princeton Bicentennial Conference in 1947.

The present paper reports the preliminary and tentative results of a statistical treatment of the numbers of taxonomic units representing various invertebrate groups during successive periods of geologic time. The sources, nature, and quantity of the basic data employed in this study are indicated on Table 1. The following graphs are statistical representations of these data in which the age and duration of the several periods are those reported by Zeuner (1946) from Holmes, Lane, Urry, and others.

TABLE 1.—CHARACTER AND SOURCES OF DATA

Phylum	Taxonomic Subdivision	Taxonomic Units Measured	No. of Units	Source of Data
Protozoa	Perforate Foraminifera	species	3192	Thalmann (1941–1947)
Coelenterata	Graptozoa	species	809	Ruedemann (1947)
Coelenterata	Tetracoralla	genera	535	Lang, Smith, and Thomas (1940)
Echinoderma	Paleozoic Pelmatozoa	species	5568	Bassler and Moodey (1943)
Echinoderma	Irregular Echinoidea	species	170	Clark and Twitchell (1915)
Brachiopoda	Inarticulata	genera	142	Schuchert and LeVene (1929)
Brachiopoda	Orthacea	species	681	Schuchert and Cooper (1932)
Brachiopoda	Pentameracea	species	120	Schuchert and Cooper (1932)
Arthropoda	Trilobita	species	373	Shimer and Shrock (1944)

ANALYSIS OF DATA

Histograms.—A simple and convenient method of plotting graphs based on two variables is by means of equal-area histograms. In the present case, time is plotted as the independent variable, the percentage of the total number of species or genera in any group in each period of geologic time being the dependent variable. Figure 1 shows the time-distribution of species in the brachiopod superfamily Orthacea and genera of the tetracorals. Because of irregularities in the data and because of the unequal durations of the time units used, the graphs are difficult to interpret except in broad generalities. That is, the graphs show the time interval occupied by the groups considered and the general times of greatest differentiation, but rates of change are obscured or exaggerated and the irregularities are confusing.

Cumulative curves.—Many of these irregularities are smoothed out and more interpretable graphs result from plotting the

same data as cumulative curves in which the percentages of genera and species in each unit of time are cumulated from zero per cent at the beginning of a group's time-range to 100 per cent at the time of extinction. Such graphs indicate the number of species or genera evolved within a genetic group at any moment in geologic time. Cumulative curves for eight invertebrate groups are plotted on figures 2 and 3. In these graphs a probability scale has been employed for the dependent (frequency) variable. The probability scale is so calculated as to represent data with a normal probability frequency distribution (i.e., with a symmetrical frequency curve) as a straight line.

The striking fact which emerges from the cumulative plots of these data on probability paper is that each distribution pattern is represented by a straight line. Therefore, the time-distribution of recognized and recorded genera (or species) in the groups considered must follow closely the symmetrical pattern of the normal probability curve.

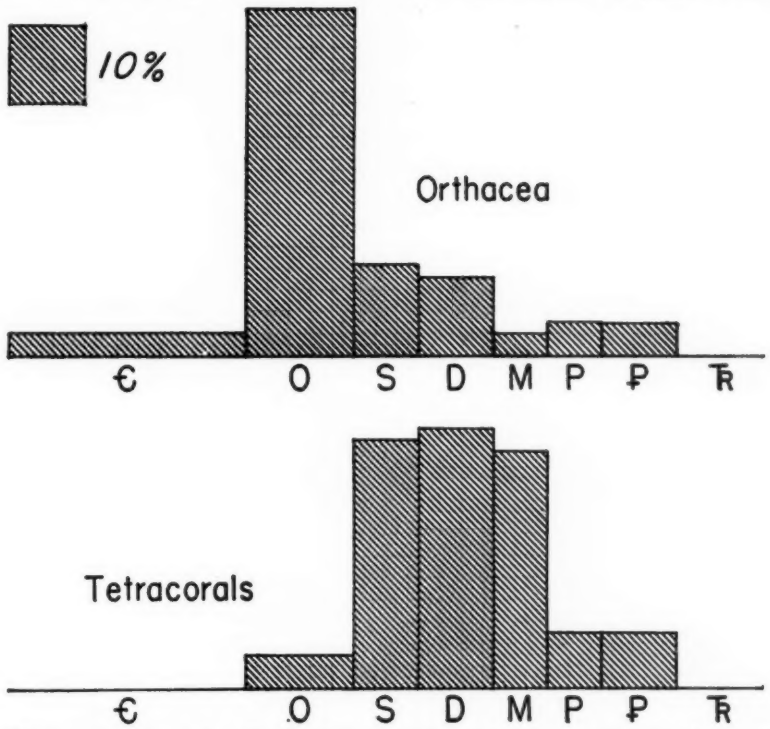

FIG. 1.—Histograms illustrating distribution of species of the brachiopod superfamily Orthacea and of genera of the tetracorals in the periods of Paleozoic time.

Frequency curves.—By reference to any standard statistical work, symmetrical cumulative curves are readily differentiated for representation as frequency curves. The resulting curves show the variations in frequency of genera or species as continuous functions of time and are not affected by irregularities in the time units employed in the basic data. Frequency curves representing the eight groups considered are plotted on figure 4.

The areas beneath all the curves are the same, the height of the median and other ordinates being determined by the standard deviation or spread of the data on either side of the median. As would be expected, where major taxonomic groups such as the trilobites and tetracorals are involved, the curves are low and widespread in contrast to the peaked characteristics of smaller groups such as the Orthacea and Pentameracea. In each case, however, the available data indicate a symmetrical distribution.

Derivative curves.—A rate of change curve

may be derived from a frequency curve by using the varying degrees of slope of the frequency curve as ordinates of the derivative curve. At each end and at the peak the frequency curve is tangent to a horizontal line; therefore, the rate of change of the frequency distribution is zero at three points and the derivative curve has a zero value at three points. At the inflection point of the rising limb of the frequency curve the rate of change reaches its highest positive value and at the opposite inflection point the rate of change reaches its highest negative value. Figure 5 illustrates the rate of change of the number of species representing a given taxonomic group as a function of geologic time.[1]

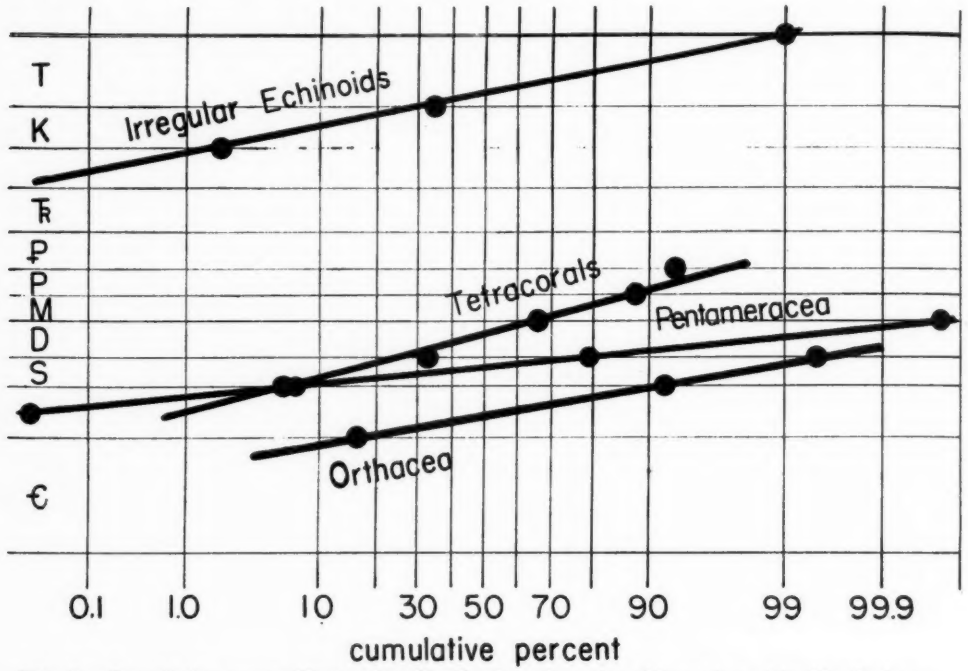

FIG. 2.—Cumulative curves illustrating distribution of species of irregular echinoids, Orthacea, and Pentameracea, and genera of tetracorals.

INTERPRETATION

Thus far this paper has been confined to the presentation of certain data and a factual treatment of them by acceptable statistical methods. Opinion as to the validity or significance of the data employed does not affect the geometry of the curves as illustrated. At this point it is interesting, if not necessarily profitable, to explore a number of problems of interpretation which are raised by these analyses. It should be made clear that, in contrast to the objective treatment of the first portion of the paper, the following paragraphs involve insecurely substantiated theory, and are subject to question on a number of grounds. It is hoped that the thoughts expressed will be received in the inquiring spirit with which they are presented.

Fundamental assumption.—Acceptance of the data on numbers of species and genera as a valid measure of the time-distribution of varying degrees of diversification of various genetic groups is the fundamental assumption required by the theoretical remarks which follow. That is, it is necessary to assume that the cumulative and frequency curves illustrated are a reasonably true representation of the distribution of the taxo-

[1] In the discussion following oral presentation of this paper H. B. Stenzel pointed out that a similar, though not necessarily symmetrical, rate of change curve would be the derivative of any species distribution pattern which rises to a climax and declines.

nomic units involved and that these are typical of the patterns to be expected in other groups.

Symmetrical distribution patterns.—If the fundamental assumption is sound, the data analyzed indicate that there is a symmetrical distribution in time of the number of species or genera of a taxonomic group about the maximum ordinate according to the equation for the normal probability curve. Therefore, the degree of diversification of a genetic group and its pattern in geologic time is systematic and subject to mathematical analysis.

Similarly, the essential portions of the curves for exocyclic echinoids and perforate Foraminifera can be constructed from pre-Quaternary data. Extrapolation as symmetrical curves suggests that the great majority of echinoid genera have already evolved and that little further diversification of this stock is to be expected, whereas the perforate Foraminifera have another 70-odd million years to go before their species are reduced to an insignificant number.

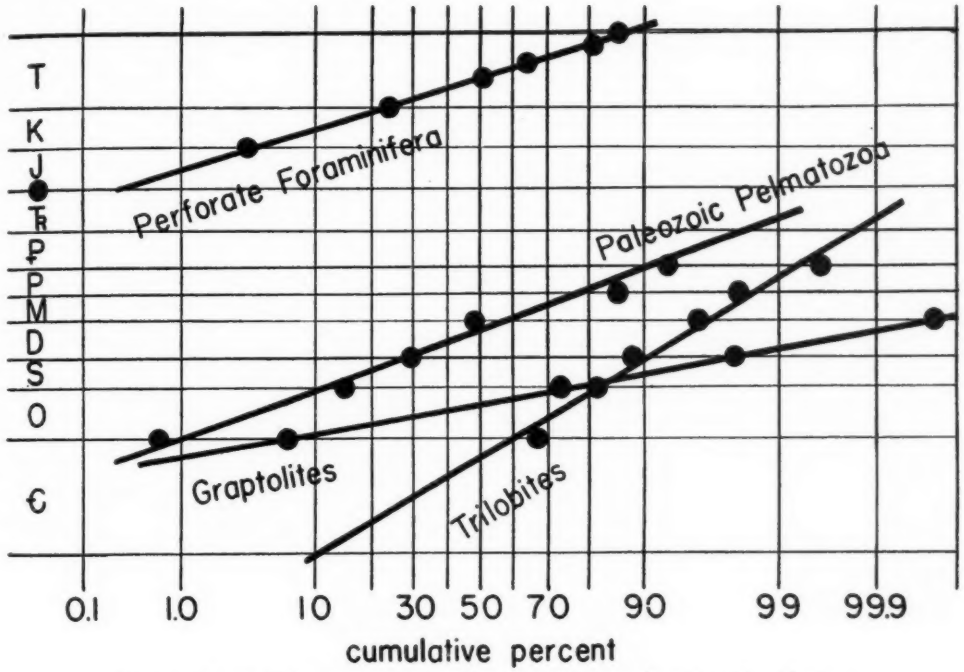

FIG. 3.—Cumulative curves illustrating distribution of species of perforate Foraminifera, Pelmatozoa, graptolites, and trilobites.

Extrapolation of distribution curves.—On figure 3 the cumulative curve of trilobite genera plots as a fairly straight line, suggesting that sufficient data are available to establish the distribution pattern of this group even though pre-Cambrian data are lacking. Differentiation to form a symmetrical frequency curve (fig. 4) indicates that an appreciable number of trilobite genera had appeared in the lineage as early as 60 million years before the dawn of Paleozoic time.

It is natural to speculate upon the possible distribution of long-range groups which had reached a high degree of diversification early in Paleozoic time. A good example is found in the inarticulate brachiopods—a group which had produced over 20 per cent of its total number of species by the end of the Cambrian and over 50 per cent by the end of the Ordovician. The cumulative curve for these brachiopods (fig. 6) is affected by loss of data in the early portions of its distribution and therefore plots as a steepening parabolic curve rather than as a straight line on probability paper. Approxi-

mate differentiation yields the skewed frequency curve illustrated by the solid line on figure 7. If it is assumed that the inarticulates had a symmetrical distribution which has been masked by lack of preservation in the pre-Cambrian, reconstruction of the symmetrical curve by addition of the broken line on figure 7 is justified. The curve illustrated has not been constructed with rigorous mathematical standards; nevertheless, it serves to suggest a long pre-Cambrian history for the inarticulate brachiopods.

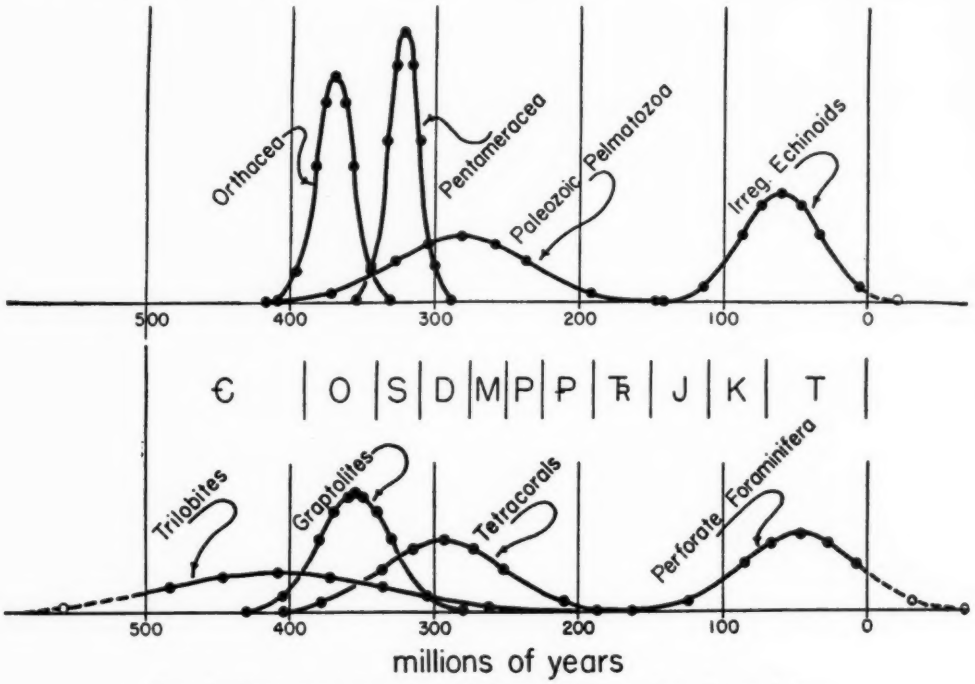

FIG. 4.—Frequency curves produced by differentiation of cumulative curves appearing on figures 2 and 3.

Relation to physical change.—What is the effect of the fundamental assumption of this paper on theories as to the relationship between physical and biologic change? If the course of diversification of each genetic lineage is symmetrical and systematic, as is here assumed, there is no apparent evidence of influence by periodic or episodic changes in the physical geography of the epicontinental seas. Several of the groups investigated were manifestly greatly reduced or became extinct by the close of the Permian and this may be attributed to environmental changes accompanying the Hercynian pulsations of Paleozoic diastrophism. However, these same groups appear to have been unaffected by similar changes associated with Caledonian orogenic phases. Other lineages are represented by smooth curves which pass without distortion through the times of Jurasside and Laramide movements. Moreover, there is no indication of synchroneity of maximal rates of change in any of the groups investigated. Such synchroneity would be an expected product of a close interrelationship between abrupt environmental changes and the nature of the biologic complex.

Rates of speciation.—Simpson (1944) has discussed speciation as one of the significant modes of evolution. The curves here under interpretation can not be directly analyzed in terms of rates of speciation since the basic data involve the numbers of species or genera recognized in various parts of geologic time, rather than their rates of appearance or extinction. However, certain

relationships are worthy of exploration in the light of assumed symmetrical distributions.

The number of taxonomic units representing any lineage during any part of geologic time is the number of units inherited from an earlier time, plus new products of speciation, and minus losses from the lineage through extinctions or taxonomically significant modifications. In considering the normal frequency curve and its rate of change derivative (fig. 8), the influence of two of these factors, rate of speciation and rate of extinction, is fairly clear. From points *A* to *C* on the curves the rate of speciation exceeds the rate of extinction with maximum increment of addition over subtraction at *B*. At *C* speciation and extinction are equal. From *C* to *E* the rate of extinction exceeds the rate of speciation with maximum loss of units from the lineage at *D*. The curves would have the same characteristics and significance under any of the following conditions:

(1) Constant rate of extinction and systematic variation of rate of speciation.

(2) Constant rate of speciation and systematic variation of rate of extinction.

(3) Systematic variation of both attributes.

Examination of the paleontologic record and its implications in genetics suggests

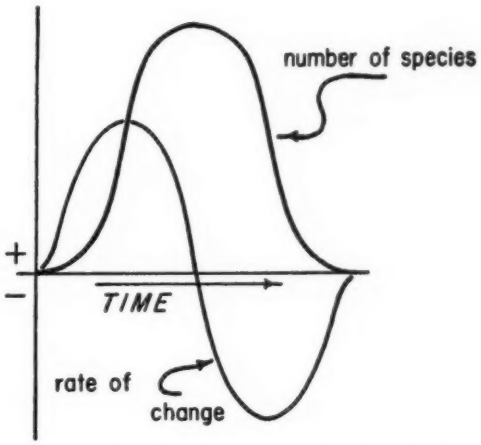

FIG. 5.—Diagrammatic curves showing relationship between frequency and rate of change.

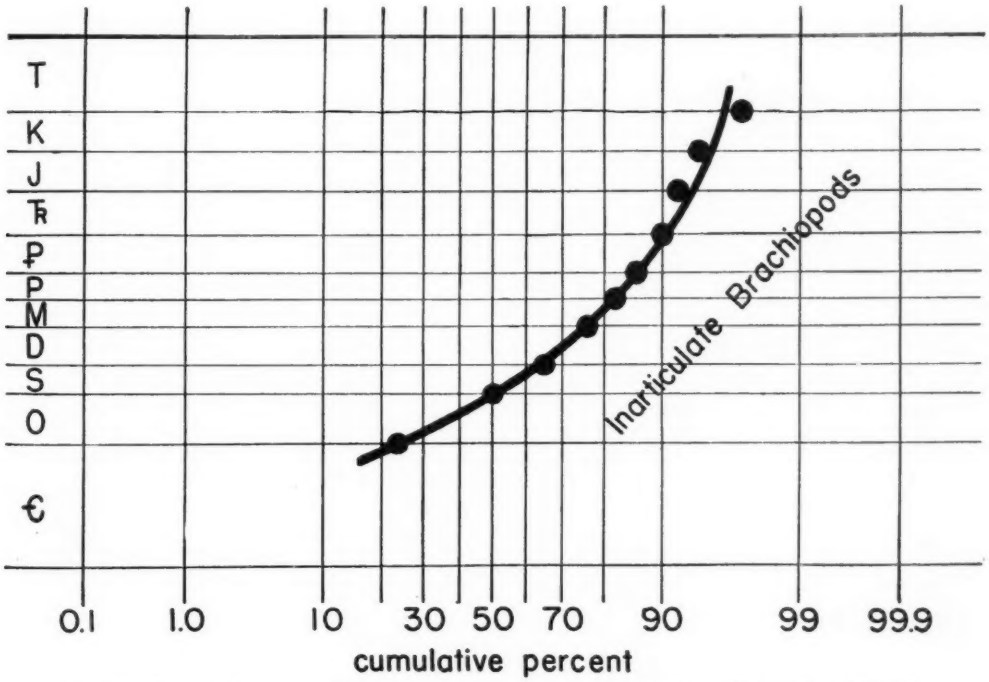

FIG. 6.—Cumulative curve illustrating distribution of genera of inarticulate brachiopods.

clearly that the last condition obtains. Speciation is obviously at a high rate during the expansion of a genetic lineage (the area about point *B* on the curves) and is definitely at a low rate at the asymptotic portion of the curve near *E*. Extinction is also at a low rate near *E*, as witnessed by the extreme longevity of remnant species, and must be low at *A*, the time of initiation of the lineage. In between, extinction may be considered to rise as new species appear, displacing less well adapted forms, reaching a climax associated with the area about point *D*, the maximum negative rate of change in the number of taxonomic units.

Factors in the longevity of individual units are more difficult to assess, but the temptation to attempt a quasi-mathematical expression is hard to resist. Again, the record indicates a marked variation during the geologic span of a lineage. Long-range "generalized" forms are evident in all groups but are conspicuous at the beginning and end of the distribution pattern; intermediate stages are characterized by species with shorter ranges. Longevity may be expected to decrease as speciation rises, increasing inter-specific competition. It is suggested that longevity of individual units falls to a minimum at point *C* when the number of units is at a maximum, rising again as extinction reduces the number of units present in any moment of time. It is clear the longevity of individual units varies in some fashion as that described, but statements as to the geometry of the variation pattern cannot be readily defended on the basis of the data at hand.

The writer's concepts of the patterns formed by variations in speciation, extinction, and longevity of units are illustrated by the hypothetical curves appropriately labeled on figure 8. Further analysis of these in conjunction with the accompanying frequency and rate of change curves suggests that the most valid index fossils in any group are those which occur near the time of maximum number of species (within the time span centering on point *C*) since this appears to be the time when minimum ranges may be expected. Moreover, correlations based on "first appearances" of species would seem to call for the utilization of groups near their maximum rates of speciation (point *B*); while correlations based on extinctions (the "bug tops"

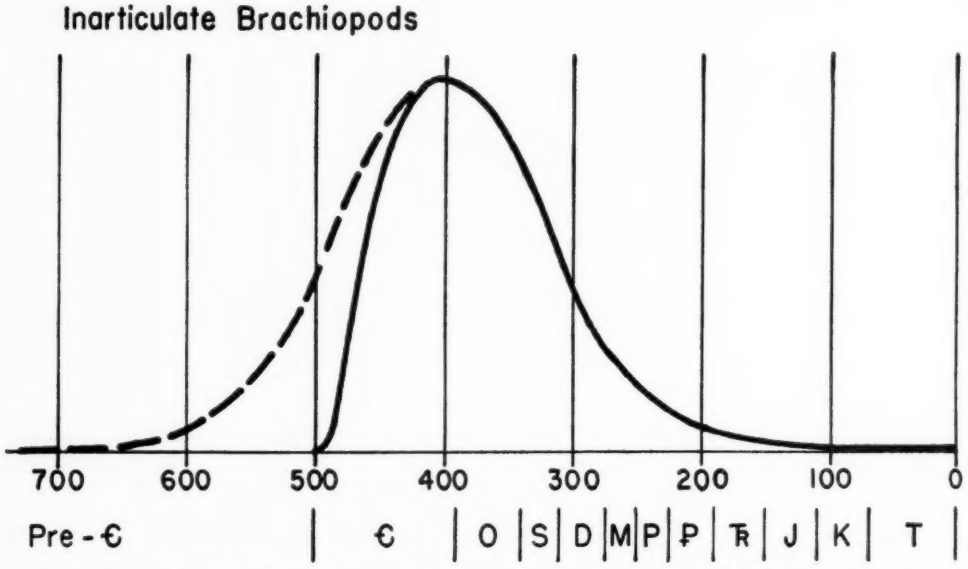

FIG. 7.—Frequency distribution of genera of inarticulate brachiopods. Solid line represents skewed pattern resulting from approximate differentiation of cumulative curve. Dashed line represents hypothetical reconstruction of distribution in a symmetrical pattern.

of subsurface stratigraphy) may be more successful if groups near their maximum rates of extinction (point *D*) are considered.

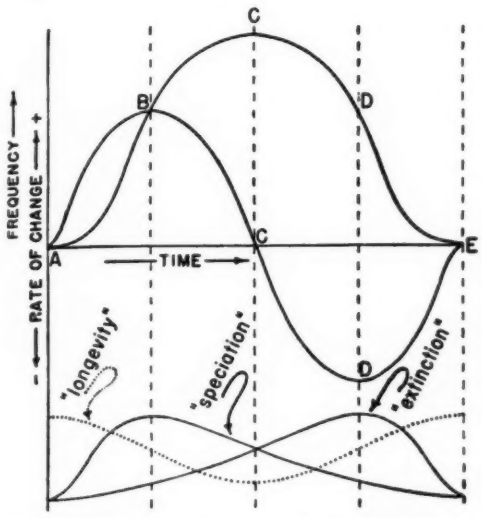

FIG. *8*.—Upper curves are diagrammatic frequency and rate of change curves for the number of taxonomic units in a hypothetical lineage. Lower curves illustrate suggested relationships between frequency distribution of taxonomic units, rates of "speciation" and "extinction," and the "longevity" of individual units. Ordinate values for the various curves are purely relative and conventionalized.

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THE STATE OF PALEONTOLOGY

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ABSTRACT—Subjective evaluation is made of the present state of paleontology, particularly in regard to some stratigraphically most useful late Paleozoic invertebrates. It is emphasized that time ranges of fossil genera are independent of major stratigraphic boundaries. Concepts of inception and migration of fossil genera are explained. The cases of *Archimedes*, *Mesolobus*, *Shumardites-Properrinites-Perrinites*, and *Triticites-Schwagerina* (in old sense) are analyzed. The principal working evolutionary hypotheses are reviewed. Attention is called to the neglect of technically difficult fossil faunas. Greater thinness of thin sections is recommended. Presence of human errors in various published quantitative descriptions is discussed. Place and value of paleoecological studies are discussed. Caution is suggested in application of genetical terms to paleontology. Application of Rules of Nomenclature to fossils is discussed. Paleontology is considered a synthesis of biology and geology.

INTRODUCTION

> Paleontology is the science which treats of the life which has existed on the globe during former geological periods. (Zittel, Text-book of paleontology)

The quoted definition exemplifies the viewpoint as to the nature of paleontology that was current in Zittel's time. Apparently no doubt existed in his mind that paleontology is not mere topographic description and cataloging of the remnants of shells, bones, plants, etc., but a science of ancient life, in so far as it can be understood by comparative study of its fossilized remains and the much more completely known living organisms. If so, the recent dispute as to whether a paleontologist is a biologist or geologist (Knight, 1947; Weller, 1947; and others) reflects the present state of minds of some of our leading colleagues, and has not been inherited from our predecessors. This dispute seems to indicate that contemporary paleontology is in a state of crisis, and that its fundamental biologic and geologic relationships are in a state of re-evaluation.

This paper is an attempt to outline, in a subjective way, the present status of paleontology, chiefly that of the invertebrates, illustrated by certain examples taken mostly from some recent studies of late Paleozoic invertebrates from the Mid-Continent region with which I am familiar. However, the conclusions reached seem to apply, with certain reservations, to the contemporary state of knowledge of other fossil organisms, here and elsewhere.

FACT AND FICTION IN PALEONTOLOGY

Stratigraphic ranges of genera.—The present state of our knowledge of fossil organisms seems to be a bewildering mixture of well established facts, stubbornly perpetuated errors, and naive notions. Only comparatively few observations and conclusions survived the test of time, and some established sequences of fossils, or some orderly temporal changes in them, have been proved reasonably constant, though usually within more or less limited provinces, while constancy of other observed changes merely is taken for granted, and as yet our science does not seem to recognize the necessity of repeated verification of fundamental observations. In this it differs sharply from such sciences as physics and chemistry, where all empirical observations are immediately checked and double checked.

Time and again attempts have been made to characterize paleontologically some major stratigraphic units of series rank by making them equal to paleontological zones, and the assumption is widespread that certain common fossil genera are unfailing zone markers. For instance, the Morrow series has been assumed to be the zone of the foraminifer *Millerella;* the combined Atoka and Des Moines series the zone of the brachiopod *Mesolobus;* the Wolfcamp series the zone of the ammonoid *Properrinites;* and so on.

This procedure of assuming or declaring some fossil genera to serve as markers for given stratigraphic units is largely wishful thinking not based on reliable facts, because the genera (and this is true for the so-called index genera) as a rule are not confined by stratigraphic boundaries of any kind. Analysis of the principles on which we paleontologists make our genera, when tested by actual findings as to how these genera actually behave in relation to stratigraphic boundaries of serial rank, reveals the following:

(1) Paleontologic genera, as we define them, do not make initial appearance suddenly within a certain comparatively short geological interval, but rather develop slowly throughout considerable geological time, usually equal to as much as one-third or more of a group, or even of a series.

(2) The period of inception, or slow, initial development of a genus, and the period of its subsequent gradual change into another genus, do not necessarily coincide with any recognized stratigraphic boundaries.

The following examples may serve as illustrations. Almost as soon as *Millerella* was declared to be confined to the Morrow series (Thompson, 1942), diligent stratigraphic paleontologists, including the author of the genus himself, found *Millerella* in the Chester below the Morrow and in the Atoka above it (Thompson, 1944, and later publications; Spivey and Roberts, 1946). Furthermore, some paleontologists believe that *Millerella* is not clearly differentiated from *Staffella* and may be treated as congeneric with it. If so, it is not surprising that *Millerella* and *Staffella* are only moderately useful stratigraphically, because both are rather long-ranging genera.

Likewise, students of *Mesolobus* have found that the medial lobe which characterizes the genus did not develop suddenly. During a fairly large part of early Atoka time, a more or less recognizable medial lobe was a variable individual character in the shells of the chonetid stock that gave rise to *Mesolobus* (Plate 26, fig. 3).

The following third example is similar but more complex. The suture lines which typify *Properrinites* develop in the ontogeny of this ammonoid when individuals attain a certain size; and at the earlier growth stages the suture is of *Shumardites* type. In the course of geological time, evolution of the *Shumardites-Perrinites* ammonoid stock proceeded exemplarily, in perfect accord with the law of phylogenetic recapitulation. During this time the *Shumardites* type of suture was telescoped back to earlier and earlier volutions and the *Properrinites* suture appeared also correspondingly earlier. Finally a new type of suture characteristic of *Perrinites*, appeared in the latest adult volutions. The evolutionary development of the stages to which the students of ammonites attach the names *Shumardites*, *Properrinites*, and *Perrinites* proceeded much more regularly than the development of the medial lobe in *Mesolobus*, the change from one type of suture to another occurring within a small fraction of a volution, and the evolution of this ammonoid stock was comparatively rapid. However, even in this case, we cannot assume that the suture changes differentiating one of these genera from another coincide with stratigraphic boundaries of a series (Wolfcamp), even though an approximate correspondence seems to exist (Elias, 1938; Miller and Furnish, 1940, pp. 139–156). Furthermore, because the collected specimens of *Properrinites* and *Perrinites* seldom, if ever, retain the living chambers, we do not know the exact maximum size of the adults, nor what kind of suture occurred in their latest adult stages. We know only at what diameter of the shell a certain type of suture made its first appearance at a particular stratigraphic horizon. Taking into account the apparent obedience of these ammonoids to the law of recapitulation we could, if we wish, define the lower limit of the genus *Properrinites* as the stage at which the typical suture appears at a particular shell diameter, and select the diameter so that this stage would coincide with the base of the Wolfcamp series, as per stratigraphic definition. Figuratively speaking this would be setting our "paleontological clock," which in this case is the evolution of sutures in the *Shumardites-Properrinites-Perrinites* lineage, so that the alarm will ring at a certain stratigraphic horizon. By comparison it is like setting the beginning of the Pleistocene period in America at an arbitrary time when glaciation first reached a certain geo-

graphic parallel in the states of Illinois or Iowa. There is nothing wrong with either procedure, and if we wish we can select such arbitrary boundaries to suit local conveniences in classification; but certainly neither of the two would be natural boundaries either paleontologically or geologically, and would not serve satisfactorily on a broader continental or intercontinental scale.

Next I wish to scrutinize some truly natural stratigraphic boundaries of some common stratigraphically important fossils, as established and verified by repeated independent observations. Some such genera indeed appear or disappear suddenly at certain definite stratigraphic horizons in certain regions. The cases of *Archimedes* and *Mesolobus* are good examples of this phenomenon. So far as known, *Archimedes* had its inception at late Silurian or early Devonian time in the area of the Cincinnati arch. It appears suddenly, however, in the Keokuk limestone (Middle Mississippian) of Iowa and Illinois, in the Batesville sandstone (Upper Mississippian) of Arkansas, in upper Desmoines strata (Lower Pennsylvanian) of Utah and in the Uralian (Upper Pennsylvanian) of European Russia. It disappeared as suddenly at the end of Chester time in Illinois and Kentucky and at the end of Springer time, which was somewhat later, in the Ardmore basin. *Mesolobus* disappeared suddenly at the end of the Desmoines in the Mid-Continent and in the Rockies, but near Moscow, Russia, it is not known below the *Teguliferina* zone or basal Uralian (Ivanov and Ivanova, 1936, pp. 20–22; 40–41), which is younger than Desmoines.

Much time and effort in deliberate and repeated field search and laboratory study has been required to establish the stratigraphic ranges of *Archimedes* and *Mesolobus* as outlined above, and even these may be somewhat altered by further investigations, although they are fundamentally correct. While at first the establishment of regionally different ranges may seem confusing, actually these discrepancies illustrate a way in which paleontology can render good service to stratigraphy, because they indicate the importance of the element of regional migration in the geological history of fossil genera. They show that when a genus truly suddenly appears in a local stratigraphic sequence, it must have migrated from another region, where it had its inception. Also, when it disappears suddenly from a local stratigraphic sequence, this does not mean necessarily that it had become extinct, but merely that the local conditions, for one reason or another, became unfavorable for its maintenance, and so it may have migrated to another place where it could continue its evolution. In fact, it was usually the environment that migrated and carried the genus with it. Such regional migrations which did not affect seriously, if at all, the uninterrupted course of organic evolution, when reasonably well established, seem to be the most dependable criteria on which inter-regional correlation can be based. They explain, for once, the old paradoxical dictum that some widely separated geological formations are contemporaneous because they carry different fossils, and are of different ages because they contain similar fossils. We now can understand just what is meant by this geological paradox.

Buckmanian hypothesis.—Another kind of wishful thinking, to which some paleontologists cling tenaciously, is illustrated by the befogged notion vaguely sketched by S. S. Buckman, in one of his numerous papers on Jurassic ammonites of the British Isles (1925, p. 9; and elsewhere). As near as one can judge, he postulated the existence of a mythical "center" of evolution of ammonites somewhere in the depths of the ocean, which, in the course of geological time, gradually moved closer to the inland seas whose ammonites are now available for study. This hypothesis was invented in order to explain the occurrence in younger Jurassic beds of some ammonites which apparently had reached a less advanced evolutionary stage than their predecessors. According to it, the primitive ammonite stock, that remained more or less unchanged at this "center" was supposed to have sent wave after wave of rapidly evolving forms to the inland seas. When, however, the "center" moved closer, the later waves had a shorter distance to travel, less time to evolve and ammonites reached the inland seas at an evolutionary stage less advanced than that of their predecessors who had to travel farther.

The phenomenon which puzzled Buck-

man and led him to the invention of this theory has been interpreted by Spath (1923, p. 65; also later publications), as a case of neoteny (paedomorphosis, or paedogenesis) or the kind of evolution that, instead of obeying the law of recapitulation, proceeds contrary to it. In ordinary evolution which follows the law of recapitulation, adult characters gradually appear in progressively earlier growth stages in succeeding generations. In neoteny, however, youthful or larval characters are supposed to have persisted longer and longer in succeeding generations. Whether or not this explains the Jurassic ammonites that puzzled Buckman, the hypothesis of evolution by neoteny is far more logical and biologically comprehensible than the Buckmanian theory. Some paleontologists, however, continue to think that the latter is applicable not only to the evolution of ammonites but also to other marine fossils.

New facts from England.—Recent startling revision of the stratigraphic occurrences of some fossils in England on which the hypothesis of evolution by neoteny was partially based, discloses that some fossils (the Jurassic foraminifer *Ophthalmidium*) do not occur in the stratigraphic order formerly supposed, but actually come in an order that seems harmonious with the theory of recapitulation (Wood and Barnard, 1946). Although the hypothesis of neoteny still seems necessary to explain some cases in apparent evolution, the field of its applicability is somewhat narrowed and recapitulation is characteristic of most evolution as revealed by paleontology. Paleozoic and early Mesozoic ammonites and late Paleozoic fusulines have furnished abundant evidence that serves as a solid foundation for the recapitulation theory and our generation of paleontologists has found it to be generally useful in the study of practically all classes of invertebrates. However, the interpretation of each evolutionary lineage, whether it accords with the recapitulation hypothesis or not, should remain open for verification and revision as newly discovered facts about previously known fossils and the discovery of new links in lineages, may improve or modify them, and thus make them more useful. If paleontology is to continue as a living science, it must be considered a mere link in the endless chain of progress.

CONFLICTS BETWEEN EXPERTS ON STRATIGRAPHIC VALUE OF VARIOUS FOSSILS

Individualism in paleontology.—Extremely individualistic attitudes in the study of fossils by some paleontologists lead them to the rejection of data and conclusions reached by anyone else but themselves. Professional feuds between such individualists have been highly entertaining in the past, but they are costly in energy and time, and do not serve the dignity or usefulness of science. In view of the tremendous difficulties and complexities involved in paleontology, both pure and applied, such extreme individualism can be ill afforded. The following example illustrates the point.

One of the ablest American specialists on Paleozoic invertebrates, who died a few years ago, was confronted with probably the most difficult stratigrapho-paleontological problem of his life when his opinion on the age of the Oquirrh formation of Utah was requested. In this formation undoubted and prolific remains of *Archimedes* occur associated with typical *Mesolobus*. At that time most American paleontologists firmly believed that *Archimedes* is an exclusively Mississippian genus, and it was also known that *Mesolobus* is restricted to the Desmoines series and its equivalents (Allegheny) of the Eastern Interior region. If the problem were presented to two men, one specializing in brachiopods only, and the other in bryozoa, there would have been an irreconcilable conflict of opinion between two experts, each supreme in his knowledge of one group of fossils. Fortunately, this paleontologist was a master in both fields, and so the conflicting evidence was carefully considered and he finally gave preference to *Mesolobus* over *Archimedes*, seemingly by a narrow margin (Girty, 1932, p. 36). The evidence of all other invertebrates, about forty-five species, some of which are in good standing as index fossils in other regions, has been given but little if any weight compared with these two genera. At present other geologists and paleontologists are generally agreed that he was correct, and *Archimedes* is now recognized as an index to strata

of Desmoines age in Utah and adjacent areas where it is unknown in the Mississippian.

Perhaps it was this justifiable deliberation in regard to the stratigraphic significance of *Archimedes* versus *Mesolobus* by the wisely cautious specialist on invertebrates that occasioned the caustic remarks concerning the "invertebrate," meaning spineless, paleontologists by his famous colleague who was an authority on Paleozoic plants. The paleobotanist declared that plants furnish far more reliable stratigraphic evidence than do invertebrates and, when similar conflicting evidence was brought to light, this time between the brachiopod *Mesolobus* and the ancestral conifer *Walchia*, regarding the age of beds near McCoy in central Colorado, the paleobotanist insisted that they are Permian in spite of anything invertebrate paleontologists might say. Since then *Walchia* has been proved to be an ecologic rather than a stratigraphic guide, and the occurrence of well-preserved late Desmoines fusulines both below and above the *Walchia* beds has established quite reliably the early Pennsylvanian age of the McCoy formation. Some narrowly-specialized paleobotanists, however, ignore this substantiation of the evidence furnished by *Mesolobus* and continue to consider the age of McCoy formation "undecided."

If we choose to disregard the great importance of the regional migration from one region to another during geological time of fossil genera and species either on a continental or a global scale, and if we summarize in a single column their total stratigraphic ranges in all parts of the world we find that:

Archimedes ranges from late Silurian to Middle Permian (Artinskian).

Mesolobus ranges from early Pennsylvanian (early Desmoines) to late Pennsylvanian (Virgil or Uralian).

Walchia ranges from early Pennsylvanian (Desmoines) to Permian or possibly Triassic.

These ranges are so great that the value of these genera as zone markers appears greatly diminished as compared with their stratigraphic usefulness to our predecessors. Actually, however, their stratigraphic value has increased because their regional stratigraphic ranges now have been established with much greater accuracy, although their ranges in different regions are not the same and always must be evaluated on a regional basis only. Further progress in their stratigraphic use will result from the recognition and application of the principle of inception and migration of paleontological genera. For instance, it seems that it can be applied effectively in the use of fusulines for regional and intercontinental correlations, as indicated in the following discussion.

INCEPTION AND MIGRATION OF SOME FUSULINID GENERA

The general evolutionary change in fusulines from *Fusulina-Fusulinella* to *Triticites* and to *Schwagerina* has been amply demonstrated and these genera are known to typify three successive stratigraphic zones in North America and Eurasia. The local boundaries between these zones, however, do not necessarily correspond in different regions. In one, some fusulinid genera show complete evolution from inception to clear-cut differentiation, while in another the same genera make their first appearance rather suddenly. Likewise, their last occurrences in different regions are far from uniform. Thus in America *Fusulina* and *Fusulinella* disappeared abruptly at the end of Desmoines time but in the Old World representatives of both genera are frequently encountered in beds of Upper Pennsylvanian and even Permian ages (Licharev *et al.*, 1939, pp. 35–36), and only at a very few places are these latter occurrences the result of redeposition.

Miss Rauser, ranking specialist on fusulines, recognizes in the Russian zone of *Triticites* a number of species closely related to, if not identical with, the American forms *Triticites ventricosus*, *T. acutus*, *T. beedei*, and *T. plummeri* which occur exclusively in the Shawnee or higher beds of the Virgil series in the Mid-Continent region. In Russia there is no underlying zone which would have slender species of *Triticites* like those in our Douglas group or Missouri series. The only described slender Russian form, *T. irregularis* var. *annulifera* (Rauser, 1938, pp. 113, 115, 156; pls. III, fig. 10; pl. IV, fig. 3) differs from American species of *T. irregularis* group from the Douglas and Missouri by having a higher spire composed of fewer volutions, which seems to indicate

a more advanced evolutionary stage.

Schwagerina is one of the most critical genera in the differentiation and correlation of the late Pennsylvanian and early Permian marine deposits of the world. This genus in its time-honored sense and as uniformly understood by paleontologists and geologists prior to 1936, generally characterizes the Wolfcamp series in Texas, the lower part of the Big Blue series in Kansas and Nebraska, and the Sakmarian in Russia, but the notion that it appeared suddenly and synchronously in all these regions has little foundation in fact and is biologically unsound. *Schwagerina*, or what is now generally termed *Pseudoschwagerina* and *Paraschwagerina*, did not appear suddenly but emerged from a period of inception and evolutionary instability, much as other genera have, and it is necessary for paleontologists to realize this.

Generic dignity recently has been given to representatives of the *Triticites* stock that have lost one or more of the following generic characters of *Triticites:* (1) presence of chomata, (2) moderate fluting of septa, and (3) uniformity in the rate of expansion of the test; or that have acquired: (2a) more intense and regularly developed fluting of septa, (3a) a distinct change in the rate of expansion of the test from gradual in early stages to rapid in the later ones. In the earlier period of modern research on fusulines emphasis was placed on the most obvious of these evolutionary changes, the "sudden" expansion of the outer volutions that results in considerable inflation of the test, and such forms have been referred customarily to Möller's genus *Schwagerina*. When Dunbar and Skinner began their task of "splitting" the old genus they introduced new names for various advanced species of the old inclusive genus *Triticites*, for example *Pseudofusulina* (1931) for forms with intense and more or less uniform fluting of the wall and with vanishing chomata. In 1936 these authors concluded, however, that their genus *Pseudofusulina* is a junior synonym of *Schwagerina*, because they had determined that in the type of the latter the outer volutions do not expand suddenly, and consequently there is no "tightly coiled juvenarium" or a stage of slowly expanding earliest volutions, while the septa are intensely fluted and there are no chomata, For these reasons they believed they had no choice but to modify the previously held understanding of *Schwagerina*, and in accord with a strict application of the Rules of Zoological Nomenclature, they decided to erect two new genera for the forms that possess the "tightly coiled juvenarium," and which previously had been classified in *Schwagerina*. In order to preserve some semblance to the name "*Schwagerina*" they coined the new names *Pseudoschwagerina* and *Paraschwagerina* (1936), the first for the forms with inflated outer whorls that possess feebly fluted septa and only rudimentary chomata, and the second for those with similarly inflated outer whorls but possessing intensely fluted septa and no chomata at all.

This new concept regarding *Schwagerina* introduced great confusion. In the older literature, and in some of the publications that have appeared since 1936, *Schwagerina* is used in the old sense, but in other recent publications it is used in the new sense.

In the meantime the rapidly increasing study of the fusulines both in America and Europe disclosed forms transitional between *Triticites* and *Schwagerina* (in the old sense) which could, therefore, be classified with equal propriety in either of these genera. American observations were made by Henderson (MS., 1932; University of Chicago Thesis);[1] and similar discoveries were made known in Russia where a species from the *Triticites* zone was described as *Triticites schwageriniformis*, which has a distinct tightly coiled juvenarium as in *Schwagerina* (in old sense) but with straight and well developed chomata similar to the most primitive but undoubted representatives of *Triticites*. If viewed in the light of Dunbar and Skinner's splitting this peculiar combination of three characters, usually consid-

[1] Some individuals of *Triticites* clearly related to *T. plummeri* and recently collected from the Ervine Creek limestone (Deer Creek formation) in the Shawnee group of Nebraska have a pronounced sudden expansion of the third and fourth volutions, and in size and shape they are much like *Schwagerina* (old sense) *kansasensis* from the Neva limestone of Kansas and the Wolfcamp series of West Texas. Detailed measurements confirm their transitional evolutionary position between these species.

TABLE 1.—DIFFERENTIAL CHARACTERS OF SCHWAGERINID GENERA

Generic Group	Juvenarium	Fluting of Septa	Chomata
Schwagerina (in new sense)	None or Rudimentary	Intense	Rudimentary
Pseudoschwagerina	Developed	Feeble	Rudimentary
Paraschwagerina	Developed	Intense	None
Meta-Schwagerina	Developed	None	Strong

ered to be of generic importance, would warrant introduction of a new generic name, let us say Meta-Schwagerina,[2] on a par with *Pseudoschwagerina* or *Paraschwagerina*. To illustrate the point the combination of the discussed generic characters is tabulated on Table 1.

These data demonstrate the actual existence within the *Triticites* stock of some species which show a stratigraphically early, decidedly pre-Permian (in American sense) tendency toward development of a "tightly coiled juvenarium," which is the fundamental character on the basis of which *Schwagerina* was formerly universally recognized.

When it is realized that neither in America nor in Europe does the appearance of this character in *Triticites* coincide with the beginning of the Permian (in American sense), a new approach to the revision of the biologic and evolutionary significance of *Schwagerina* is opened, such as follows.

Text figure 1 is a non-logarithmic graph illustrating the rate of expansion of the tests in a group of sub-spherical species of *Schwagerina* (in old sense) in which the successive volutions are plotted horizontally and their height vertically. The curves are typically sinusoidal, as they should be, because they indicate the growth rates. Growth of most organisms, including man, starts slowly, then accelerates gradually, but eventually slows down again, and may even be reversed in a senile stage. Thus a normal curve of growth is sub-horizontal at infancy, becomes more and more steeply inclined during adolescence and then levels off until it again becomes sub-horizontal at full maturity, and may even turn downwards in old age.

Growth curves of the sub-spherical species in the graph are plotted from measurements of the height of volutions (or measurements of equatorial diameter recalculated to the height of volutions) from publications by Beede, Dunbar and Condra, and M. White, and also from unpublished measurements by Ryniker and myself. The rate of growth shows a distinct tendency to increase during the course of geological time. The graph of the earliest form, *T. consobrinus* is only slightly curved. In the succeeding *T. plummeri* and *T.* n. sp., curvature becomes more and more pronounced, and the change from a slower growth in infancy to faster adolescent growth becomes more evident although it cannot be detected easily by a visual inspection of specimens in cross sections. Consequently descriptions may state

[2] I do not intend to actually introduce a new generic name for the Russian form, no representatives of which are at my disposal. Hence Meta-Schwagerina remains quite available for formal introduction to this or any other fossil.

TABLE 2.—SPECIES FOR WHICH GROWTH-LINES ARE PLOTTED IN TEXT-FIGURE 1

Species	Source of Information	Stratigraphy	Locality
Schwagerina uddeni	Beede and Kniker, 1924, p. 27	Lower Wolfcamp	W. Texas
Schwagerina uddeni	M. White, 1932, p. 63	Lower Wolfcamp	W. Texas
Schwagerina kansasensis	Dunbar and Condra, 1927, p. 117	Neva limestone	S. Kansas
Schwagerina princeps	Dunbar and Skinner, 1936, p. 87	Uralian or Artinskian	Russia
Triticites, new species	Ryniker MS	Dover limestone	Kansas
Triticites plummeri	M. White, 1932, p. 63	Gunsight limestone	N. Texas
Triticites plummeri	Elias, MS	U. Oread limestone	Kansas
Triticites consobrinus	M. White, 1932, p. 41	Jacksboro limestone	N. Texas

that increase in height of volutions "appears to be gradual," but accurate measurements and plotting of the growth rate may show that this is not so. Only in *Schwagerina kansasensis* and *S. uddeni* does this change become so great as to be obvious, and a "tightly coiled juvenarium" clearly is present. In other words, the acceleration of growth in the adolescent stage is so great and results in such a sudden change in the manner of coiling that it is easily detected by the eye. This character is easily noticeable in the more typical forms of *Schwagerina*, but it is not in the less typical ones because they are transitional in the evolutionary series. Plotting of growth lines in *Schwagerina princeps* and *S. montiparus* (solid lines in the figure) shows clearly that they belong in such a transitional stage. They are more advanced than *Triticites plummeri* and *T.* n. sp., but are less so than the most primitive recorded example of *Schwagerina kansasensis* from the Neva limestone of Kansas. The illustrated sections of *Schwagerina princeps* and *S. montiparus* (Pl. 26, figs. 1, 2) after Dunbar and Skinner also show by measurement, if not by observation, that the inner three or four volutions expand at a slower rate than the outer ones, and a tendency toward the development of a tightly coiled juvenarium is evident. These sections are presented at a magnification greater than the original, and dashed lines have been added to facilitate this observation.

Some genera in both neo- and paleontology have been based on designated species that proved to be untypical of the genera as they had come to be generally understood. Such unfortunate selections of types as a rule have not been considered sufficient reason for changing the generic concepts based on them. Thus we could, if we wish, retain the generic concept of *Schwagerina* in the old sense by merely recognizing that its genotype happens to have the "tightly coiled juvenarium" in an imperfect early stage of its phyletic development, and in doing so we would act within the Rules of Zoological Nomenclature.

The authors of the new concept of *Schwagerina*, however, did not follow this procedure but decided to restrict this genus to species which do not have a sufficiently "tight" coiling of early volutions, and to differentiate from them those forms in which the "tight" coiling of early volutions becomes more obvious. As in the case of *Properrinites*, we may say that the "paleontological clock" provided by the *Triticites-Schwagerina* (in old sense) evolutionary lineage has been set by them so that the

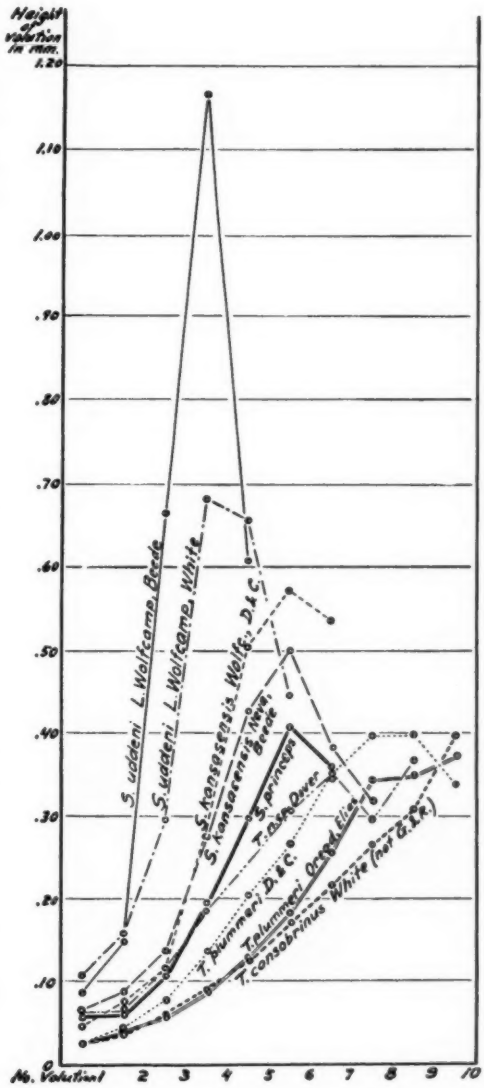

FIG. 1—Growth curves of some subspherical species of *Triticites* and *Schwagerina* (old sense). See explanation in text.

alarm will ring when the particular degree of coiling in the juvenarium has been reached which coincides with the Pennsylvanian-Permian boundary, as accepted in America. There is nothing fundamentally wrong with this procedure and it seems to work satisfactorily in the Mid-Continent province. It would be presumptuous, however, to expect that an equal coiling of the juvenarium in *Pseudoschwagerina* and all similar genera must necessarily be reached at the same instant of geological time everywhere, and we know that certainly it did not in at least the case of Meta-Schwagerina (*Triticites schwageriniformis* Rauser-Cernoussova, 1938).

If, on the other hand, we should wish to work out fusulinid evolution without attempting to fit paleontologic genera to local stratigraphic boundaries, we might return to the old concept of *Schwagerina*, in its broad polyphyletic sense, characterized by acceleration of growth after the first three to five whorls; or, if we wish to recognize smaller monophyletic genera, most of the named groups introduced by Dunbar and Skinner can be used but with the understanding that the "schwagerinid stage," as it may be called, was reached in different genera at different times which do not necessarily correspond with important but local stratigraphic boundaries.

PALEONTOLOGIC GENERA AND SUBGENERA, AND RULES OF NOMENCLATURE

The foregoing examples of the evolutionary relations of some common paleontological genera seem to warrant the following conclusions.

1. Original establishment of paleontological genera is usually arbitrary. At the time of their establishment, their evolutionary relations are rarely well known and later discoveries frequently prove that their designated types were not satisfactorily selected.

2. Most neontological genera are comparatively easy to delimit because only their living representatives matter, and their geologic history need not be considered. Most of them are well differentiated from each other and only few occasion trouble in taxonomic treatment because of close relations to other living genera.

3. Paleontological genera, however, are difficult to delimit because they grade into each other through intermediate forms, and in most if not all of them may be recognized a stage of inception, a stage of differentiation, and in many also a final stage of evolution into later subgenera.

4. The Rules of Zoological Nomenclature were set up by zoologists primarily for the taxonomic treatment of living organisms, and they do not provide for several of the characteristic difficulties encountered in paleontologic genera. Strict application of the Rules to paleontologic genera, especially retroactive application to genera of long standing, often leads to confusion instead of clarification and uniformity.

This statement does not imply hostility to the idea that rules of nomenclature are necessary, but it suggests that paleontologic genera must be recognized as different from neontologic ones, and that they require special consideration (of course any neontologic genus becomes paleontologic as soon as fossil representatives are discovered). A paleontologic genus, especially one useful in stratigraphic correlations, should not be subject to radical change in definition when it is discovered that its type was poorly chosen. If necessary, such re-definition or revision should, as a rule, be based only on a more or less *complete revision* of as many of its

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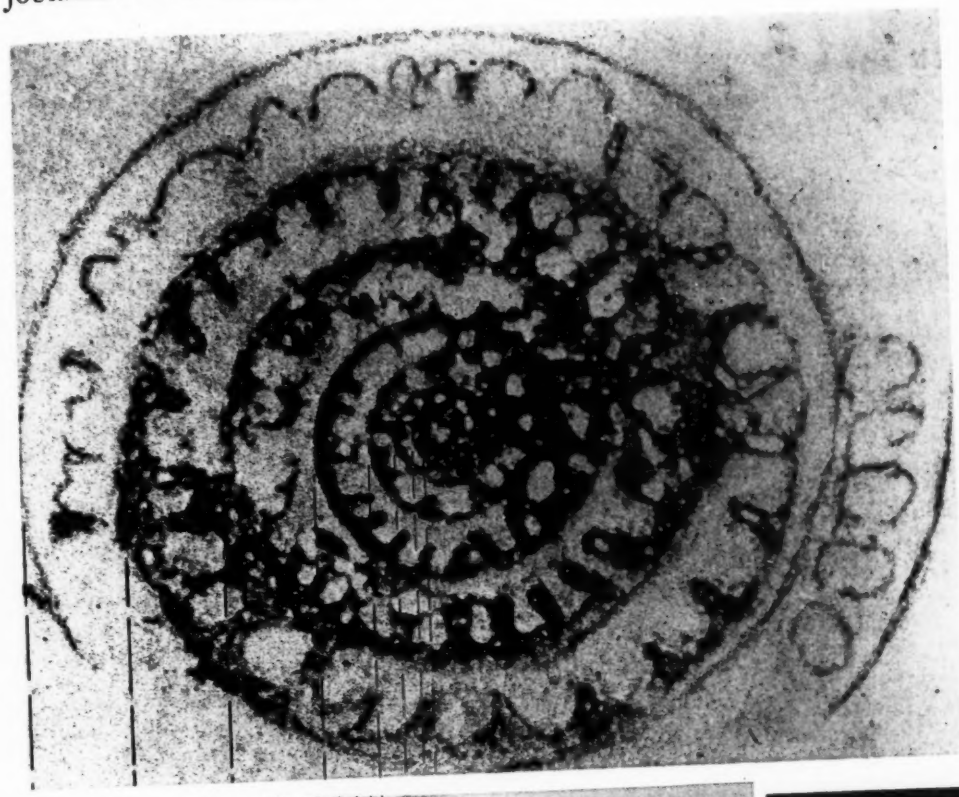
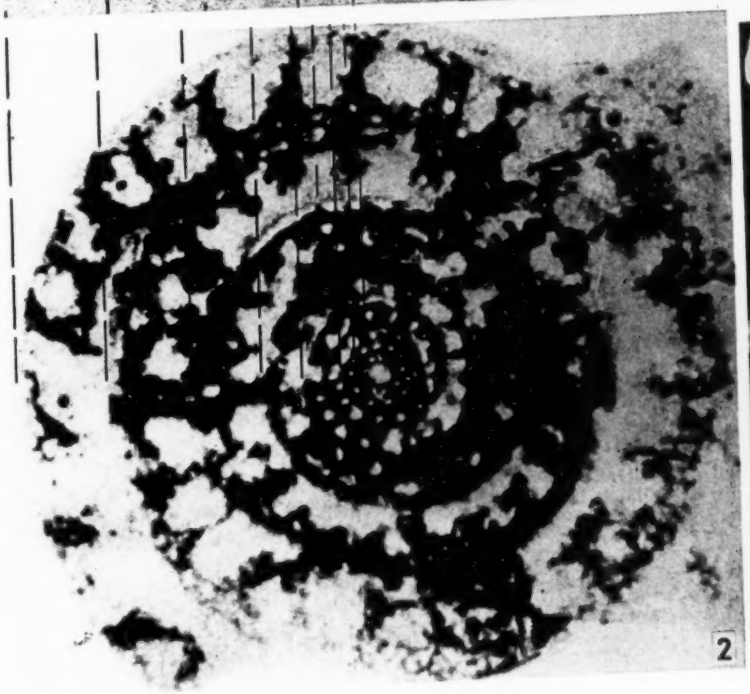
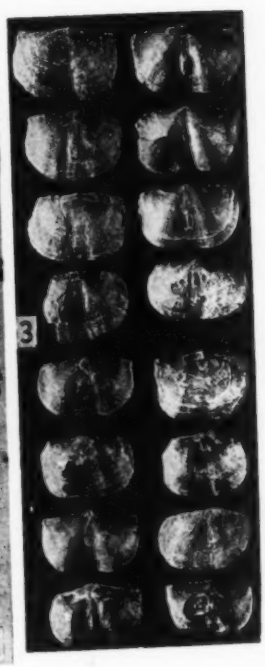
EXPLANATION OF PLATE 26

FIGS. *1, 2*—Cotypes of *Schwagerina* Möller. *1, Borelis princeps*, sagittal section of specimen 18 from the group of individuals associated in Ehrenberg's original rock specimen, from pl. 10, fig. 11, Dunbar and Skinner, 1936; ×40. *2, Alveolina montipara*, sagittal section of specimen 17, from the same rock specimen, from pl. 10, fig. 14, *ibid.*; ×40. Dashed lines emphasize change in rate of expansion which increases perceptibly after the first three or four volutions. (p. 147)

3—Chonetes [*Mesolobus*] *striatus* Weller, from basal part of McCoy formation exposed at Bond, Colorado, collected and photographed by M. K. Elias; ×1. (p. 141)







Elias, State of paleontology

representative species as possible, including those representing its geologically early inception, and others representing its differentiation into geologically later genera or subgenera.

5. Nomenclatorial recognition of a new kind of paleontological subgenus seems necessary. Any representative of a paleontological genus that shows a distinct trend toward another genus that succeeds it in geological time may be properly designated as a subgenus. No new name for such a subgeneric stage is necessary, however, because the name of the succeeding genus may be used in a subgeneric sense. Thus, a form in evolutionary transition from *Chonetes* to *Mesolobus* might be designated *Chonetes* [*Mesolobus*]; a form in transition from *Triticites* to *Schwagerina* as *Triticites* [*Schwagerina*] or *Triticites* [*Pseudoschwagerina*]; etc. According to this plan the subgeneric name in square brackets has a special meaning distinct from that implied by a subgeneric name enclosed between parentheses. The latter usage, as legalized in the Rules, does not imply the gradational evolutionary relationship indicated by square brackets.

6. Difficulties encountered in the differentiation of various paleontological genera differ greatly depending in part on the generic concepts entertained by specialists. At present there is a general tendency to recognize as natural genera groups that originated from a common progenitor and are united in an uninterrupted evolutionary sequence. Many new fossil genera, however, have been erected because a small number of specimens looked too different to be included in any previously recognized genus. Later other similar appearing species were added and the concept of the genus gradually expanded. Many genera of this type were subsequently found to be polyphyletic. From the evolutionary standpoint they are not natural and it has become customary to split them into smaller and supposedly more natural groups. There remain in use, however, many useful genera which in the future probably will be proved to be polyphyletic.

SPECIAL CARE OF FOSSILS FROM DIFFICULT BUT IMPORTANT LOCALITIES

Techniques in the preparation of fossils for study have reached high perfection but they are not utilized uniformly or systematically. Collecting in the field is mostly crude and casual, and generally little attention is paid to the occurrence of fossils in space either in relation to each other or to lithologic features. Some fossils in some beds which do not weather out readily and are difficult to find or to collect remain undiscovered or poorly known, but not because of lack of techniques at our disposal. Many gaps in fundamental paleontologic knowledge certainly can be filled by determined effort.

The invertebrate fauna of the Springer formation is a case in point. Some 30 years ago a prolific fauna was discovered in this oldest Pennsylvanian formation (now ranked as series) of America. The first large collection was deposited at a certain university but was not studied and eventually was forgotten and lost. It was not forgotten, however, by a certain geologist at Ardmore who desired a better understanding of the relationship of the Mississippian to the Pennsylvanian formations in southern Oklahoma. He rediscovered the old locality, found three more and collected from all of them. Practically all of these fossils occur as fragile molds and casts which are packed closely together. Brachiopods, bryozoans, mollusks, ostracodes, crinoids, and other invertebrates are richly represented and about 175 species in 100 genera have been distinguished.[3] The number of species and the preservation of their details equals or exceeds any other fauna known from the late Mississippian or early Pennsylvanian formations in America. The Springer fauna is a very important link connecting our Lower and Upper Carboniferous faunas, and its study will add much to our knowledge of their relations. Such faunas should not continue to be neglected merely because their study requires the application of more complicated and delicate techniques and the investment of more time, patience and understanding.

HOW THIN SHOULD THIN SECTIONS BE?

Much time and effort have been devoted to the development of techniques for cutting thin sections and staining them, but not

[3] A monographic description of this fauna has been submitted for publication.

enough attention has been paid to attaining greater thinness. Biological sections prepared by the microtome are much thinner than the average paleontological slides, which are about 10 to 20 microns thick. The study of some delicate but important structural details of fossils requires sections not more than 1 or 2 microns thick; and methods have been developed to obtain them. Also, by the careful regulation of light and the proper selection of lenses good microphotographs of thin sections frequently can be made without staining. In one of the latest applications of these methods a fossil previously identified as a hydrozoan coral, and later described as a fossil alga, has been proved to be a fragment of the back bone of a cuttle-fish or squid.

TABLE 3.—COMPARISON OF THE MEASUREMENTS MADE ON THE SAME SET OF SLIDES OF *Triticites primarius* MERCHANT AND KEROHER

Characteristic Element	Merchant and Keroher, 1939	Burma, 1942
Volution number	6.–6½ (to 7½)	6–6½ (to 7½)
Form ratio	average 1:4.1	1:3.18
Form Ratio	minimum 1:3.9	1:2.61
Form Ratio	maximum 1:4.6	1:4.05
Radius vector (5th vol.)	average .72	average .729
Half Length	average 4.7 (4.5 to 5.1)	(7th vol.) 4.17 (3.29–4.32)
Proloculum dia.	.149 (.130–.166)	.140 (.096 to .168)
Height vol. (5th vol.)	.220 (.165–.250)	.220 (.156–.300)
Wall thickness (5th vol.)	.064 (.055–.070)	.062 (.048–.072)
Septal count (5th vol.)	21 (17 to 24)	21½ (18 to 25)
Tunnel angle (5th vol.)	44° (30 to 54)	48½° (36½ to 65)

HUMAN ERRORS IN MEASUREMENTS AND COUNTS

One of the most common errors in the record of measurements is the discrepancy between dimensions stated in the text and the corresponding dimensions that can be measured on published illustrations whose scales are indicated. Differences commonly amount to as much as 10 or 20 per cent but occasionally they are much greater. Generally measurements given in the text are correct or nearly so, and it is the scale of illustrations that is more likely to be wrong. This is because photographs are rarely taken at exactly the scale intended or indicated by the author, and further departure from the indicated scale may occur because the engraver of the plates or cuts has not followed instructions regarding reduction precisely. Serious discrepancies result, however, in some measurements made with the aid of a hand lens or microscope.

In table 3 are compared two sets of published measurements made from the same set of thin sections of *Triticites primarius*. Several of the measurements are reasonably close but the indicated form ratios particularly are quite divergent. This species is slender and the ends of specimens are easily damaged or broken off by natural processes or by preparatory work. The original authors measured the lengths of undamaged or restored specimens and their values are substantially greater than those of the subsequent reviser.

The only effective way to eliminate or reduce occasional errors in microscopic measurements and counts is to publish accurately scaled microphotographs on which measurements can be made and verified by the reader. Also, the making of original measurements from much enlarged photographs of thin sections is recommended. Enlarged prints can be made directly from sections used as negatives in a projection printer (this method was demonstrated to me by my son, Maxim M. Elias, in 1937 when he was a graduate student at the University of Illinois).

Some authors (Moore, 1929, footnote p. 15; Condra and Elias, 1944 pp. 54–55) have shown already that inevitable discrepancies in the counts of certain elements of fenestrate bryozoans (*Fenestella* and others) depend upon the method used, and many other kinds of individual errors occur in both the old and new professional literature.

Perhaps special periodic reports noting such errors should be published, so that paleontologists can correct them in the books of their libraries.

The necessity for accurate recording of the quantitative data on fossils becomes increasingly important with growing demands for greater accuracy in the use of fossils in stratigraphy. Statistical study of fossil populations, involving the measurement of many instead of only one or a few individuals, is gaining in popularity among paleontologists, but reliability demands that proper methods, procedures and standardizations, such as worked out by biologists, be employed.

PALEOECOLOGY IN RELATION TO THE STUDY OF EVOLUTION

Little is known about the ecology of fossil assemblages and the necessity for paleoecologic studies is not generally recognized although this is certainly complementary to the study of evolution. It seems self-evident that the understanding of an organism is incomplete until its relations to its neighbors and surroundings are known.

It is well known that heredity determines fundamental structure of individuals through gene-control, but environment modifies this structure in certain ways. Thus an individual is a result of combined control by heredity and environment. Populations living in certain environments have some common traits that set them apart from other populations of the same species living under different conditions. For instance, the average size of adults usually depends on climatic conditions controlled largely by temperature.

The restoration of past environmental conditions is usually very difficult but the fact itself that conditions differed is easily established. Evidence of this is furnished by the different associations with other fossils and their occurrence in different kinds of rock.

The following is an example of an apparent environmental effect. When comparing some obviously closely related fusulines collected from several different horizons, orthogenetic changes were detected, being expressed by a progressively increasing height of volutions, which results in progressively larger equatorial diameters. However, it has been found that at a few particular horizons whole populations lack one or two last volutions but otherwise fit perfectly into the evolutionary lineage. This lack of the late adult volutions in the observed fusulines seems due to environmental control preventing attainment of full growth by individuals. However, the apparent difference in environment did not seem to prevent normal propagation of the undersized population, nor did it alter the course of orthogenetic evolution of the lineage.

Although the environmental factors responsible for such a situation may not be understood, it is important to realize that their influences have been effective. Thus it seems feasible, at least in some cases, to separate the apparent changes induced by them from orthogenetic evolutionary changes, the establishment of which is extremely important in current detailed stratigraphic work.

PALEONTOLOGIC *versus* GENETIC TERMS

Distinguishing between individual variations, biologic mutations, and environmental modifications in closely related fossil populations is very difficult and the term mutation, as used by geneticists, in paleontology is generally quite uncertain of application. Paleontologists engaged in the study of gradual evolutionary changes in fossil populations have frequently used for them the term mutation in its original, paleontological or Waagenian sense (Swinnerton, 1923, pp. 57, 390; Muir-Wood, 1928, p. 3), and it does not seem justifiable to insist that they discontinue the employment of this useful term for fossil organisms because geneticists use it in a different sense for extant organisms. By comparison one may mention the fact that zoologists use generic names for animals that duplicate generic names used by botanists for plants—and yet this practice causes no serious difficulty in biology. It seems that paleontologists can gain nothing by using this term in its genetic implications without actually knowing that they are dealing with truly genetic mutation.

Another useful paleontological (as well as biological) term that is unjustly criticized is variation.

The virtue of the paleontological terms

mutation and variation is their neutrality, as they do not imply meanings comparable to the biological terms mutation and modification. Although it may be desirable (or at least theoretically possible) to interpret fossil populations in terms of genetics, the time-honored use of the neutral paleontologic terms should not be lightly discarded for the great majority of evolutionary changes established by paleontologists.

Undue eagerness to trade paleontologic terms for genetic and biologic ones often is accompanied by failure to understand correctly the meaning of these terms. For instance, the well known and widely observed phenomenon of phyletic increase in the size of fossil organisms has commonly been called gigantism, a term widely used in biology to indicate abnormal growth of individuals. If we are determined to find in fossil organism, the same phenomena that are recognized in living ones, it would seem wise to reserve this term for individual abnormal fossil specimens.[4] Likewise, the term *hypermorphosis* coined by embryologist deBeer (1940, pp. 29, 65) to indicate the case of "overstepping" in ontogeny of evolutionary lineage, has been subsequently used by geneticist Schmalhausen (1946, p. 459, 470) to indicate the particular case of "overdevelopment with a loss of coordination with the environment" a condition that is generally "inadaptive" and it was proposed to distinguish this abnormal and harmful phenomenon from "the general increase in size, which is not infrequently observed in some phyletic branches. These increases of size are generally obviously adaptive."

The application of this term to the phenomenon of the normal phyletic increase in size of ammonites (Newell, 1948, p. 1342) in either deBeer or Schmalhausen's sense may be questioned.

A safe and quite appropriate procedure in describing minute changes in fossils is to call them variations, if horizontal or synchronous, or paleontological mutations (waagenons,[5] if you please) if vertical or heterochronous. Paleontologists who wish to indulge in the difficult and dangerous task of interpreting these changes in terms of contemporary genetics may do so at their own risk, but should refrain from confusing the existing orderly paleontological record which grows by our joint efforts and will always remain open for various advanced biological interpretations.

[4] For a correct application to fossils of the biological terms gigantism and dwarfing, see the classical monograph on "The British Carboniferous *Producti*" by H. M. Muir-Wood, 1928, p. 11.

[5] Provisionally introduced by Caster 1949, and supported by Elias (MS).

NOMENCLATORIAL RULES IN PROPER PERSPECTIVE

Much progress in orderliness and uniformity has been achieved in the field of paleontologic taxonomy. Some paleontologists, however, seem to lose sight of the subservient role of taxonomy to biology and worship taxonomy as an end in itself. The naive notion seems to be held that as soon as all the fossils are described and listed with proper regard to man-made taxonomic Rules, the fossils will automatically fall into a complete and perfect evolutionary pattern.

Rigid adherence to the present taxonomic rules require their retroactive application and many times has resulted in the rejection of an old and well known name in favor of a new and unfamiliar one or an older one long ago forgotten. The unrealistic notion is widely held that, as soon as such a change has been legally made, all paleontologists can forget the discarded name, that progress has been made and no harm done. Experience proves, however, that in each case paleontologists are invariably burdened with the necessity of remembering two names rather than one because this practice does not magically substitute new names for old in the previous literature which is indispensable in any thorough study. Part of the difficulty results from the fact that zoological and botanical rules of nomenclature are applied to incomplete fossil remains for which they were not intended. An example of the type of confusion that arises has been mentioned previously in this paper. Strict application of the present rules inevitably leads to arbitrary legalistic decisions rather than reasonable ones, especially when retroactively applied. The current practice of changing time honored names usually leads to confusion instead of uniformity, complicates unnecessarily an already existing

complex situation, and constitutes waste of effort, time and printed paper, all of which are badly needed for essential and useful research.

COMPLEXITY OF PALEONTOLOGY

Empirical use of fossils may cause them to be regarded merely as part of the lithologic characteristics of a rock formation, and as such they are an important part of sedimentary petrology. Paleontology, however, demands the recognition of fossils as the remains of organisms, and as a science it is a synthesis of biology and geology. No short cut to the proper understanding and practical use of fossils in geology exists that by-passes biology, and the paleontologist must be both a biologist and a geologist even if this may require almost superhuman effort on his part.

Some parts of biologic science are so well advanced that they may be applied immediately by the paleontologist providing he can find this useful information in the complex biologic literature, but occasionally problems encountered by the paleontologist require purely biologic studies that have never been previously undertaken. Only a few paleontologists have the courage and background to attack effectively such complex problems, but their work has a far reaching effect on the progress of the whole structure of earth sciences. It belongs in the domain of the basic research.

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THE *CODASTER ALTERNATUS-CODASTER PYRAMIDATUS* GROUP OF BLASTOIDS FROM THE MID-DEVONIAN OF NORTH AMERICA

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ABSTRACT—Lyon (1857), Shumard (1858) and Rowley (1902) described several species and varieties of blastoids from the richly fossiliferous Mid-Devonian rocks at the Falls of the Ohio River and elsewhere in the vicinity of Louisville, Kentucky. Several closely related species of *Codaster*, to which we refer as the *Codaster alternatus-Codaster pyramidatus* group, were first described from this area and subsequently were reported from other localities. Because the species are gradational and because the original descriptions and illustrations are inadequate, misidentifications and spurious reports of geologic occurrence are commonplace in the literature. This paper summarizes the results of a restudy of the original type material, plus all specimens that we could locate in repositories throughout the country, and specimens that we have collected. No new species are described, but one variety is raised to specific rank, one species is illustrated for the first time, and one species or variety is suppressed as a synonym.

INTRODUCTION

OBJECTIVES of this study.—While restudying the Devonian blastoids of North America the writers learned that much confusion existed regarding the relationships of *Codaster alternatus*, *C. pyramidatus*, and some related species of blastoids described originally from Mid-Devonian strata in the vicinity of Louisville, Kentucky. A study of specimens in various museums, specimens collected by us, and a review of the literature has revealed that the species of the *Codaster alternatus-Codaster pyramidatus* group have been confused repeatedly and should be studied anew. The purpose of this paper is to define more clearly the characters of the species of this group and to establish their stratigraphic positions as closely as possible.

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STRATIGRAPHIC OCCURRENCE

Richly fossiliferous Devonian strata in the vicinity of Louisville, Kentucky, and the adjacent part of southern Indiana have been a favorite source of collections for paleontologists for well over a century. In addition to the fine outcrops at the Falls of the Ohio, extensive quarrying operations afforded good collecting from Onondaga and Hamilton strata along the various branches of Beargrass Creek in and near Louisville and also north of the river in southern Indiana. Blastoids are rare in present-day exposures and they probably were never very numerous, but altogether the Devonian of this area is known to have yielded several hundred specimens of which we have suc-

ceeded in locating and studying nearly two hundred. Insofar as we are aware, the largest lot of Devonian blastoids collected in this area is now in the Springer Collection at the United States National Museum. This valuable collection contains Lyon's types of *Codaster alternatus*, the lectotype of *C. pyramidatus* Shumard, the type of Wachsmuth's *Heteroschisma alternatum* var. *elongatum*, topotype material of *C. americanus* Shumard, and numerous other specimens. Dr. Harold E. Vokes called our attention to the presence of the G. K. Greene Collection in the American Museum of Natural History. This famous old collection from the Louisville area, made over a period of many years, contains the types of *C. attenuatus* var. *robustus* Rowley and the other blastoids described and figured by Rowley (1902) in G. K. Greene's "Contributions to Indiana palaeontology."

Our efforts to determine the precise stratigraphic position of the blastoids in these old collections have not been entirely successful. Some of the specimens were collected before the Devonian of the Louisville area was differentiated into Onondaga and Hamilton, and consequently the accompanying labels merely state that they came from the Devonian at the Falls of the Ohio. According to Guy Campbell (personal communication, July, 1948), who has collected in the Devonian of southern Indiana for many years, and is thoroughly familiar with its stratigraphy, the problem is complicated by the fact that many of the better specimens, some of which are partially or wholly silicified, were collected from the residuum of two or more formations, *i.e.*, the Beechwood and Silver Creek, and in some cases the residuum contained mixed Onondaga and Hamilton faunas.

With the expectation that it would be a relatively easy matter to determine the stratigraphic range of the species of *Codaster* represented in the museum collections, the senior writer collected in the Devonian of southern Indiana and northern Kentucky for several days during July, 1948, a part of the time in the company of Mr. Campbell. The number of specimens obtained was disappointingly small and, whereas we may know that a species is represented at a certain horizon, we can not be sure that the total vertical range is not greater. Most of the quarries in this area are old, many of them having been opened during the last half of the nineteenth century when the Silver Creek hydraulic limestone was the basis for a thriving natural cement industry and many of them have not been worked for fifty years. In crinoidal limestones like the Beechwood, blastoids and crinoids are best collected on the weathered surfaces of joint planes and the upper surface of the bedrock soon after the mantle has been removed. These weathered surfaces will yield but one crop of blastoids and crinoids, and once they have been harvested it is practically impossible to obtain a complete calyx. Specimens can rarely be broken whole from fresh limestone, as brachiopods can be, but tend to disintegrate into individual plates.

Table 1 shows the stratigraphic positions of the valid species of *Codaster* described from the Devonian of the Louisville area. *C. robustus* appears to be restricted to the Beechwood member of the Sellersburg formation. *C. alternatus* seems to be confined to the Onondaga, notwithstanding reports of the species from the Hamilton. The type specimens came from just below the *Nucleocrinus* bed in the upper part of the Jeffersonville formation and all other specimens that have been located accurately with respect to stratigraphic position seem to have come from the same zone. Reports of this species outside the Jeffersonville formation seem to be based on misidentification of specimens, *i.e.*, all specimens of *C. alternatus* reported from the Columbus limestone of Ohio have proved to be *C. pyramidatus*. *C. pyramidatus* occurs in the Onondaga in Kentucky, Indiana, Ohio and New York, and Stauffer (1915, pp. 81, 127) has reported it from the Onondaga of southwestern Ontario. In Kentucky and Indiana it is found with *Nucleocrinus verneuili* and *Paraspirifer acuminatus* in the upper Jeffersonville and it occurs in zone H at the top of the Columbus limestone in Ohio, where it is associated with the same species. At least one representative of the species has been found in New York. All of the specimens of *C. americanus* that we have seen came from the Jeffersonville formation at Louisville, apparently from the upper part of the formation.

TABLE I.—STRATIGRAPHIC RANGE OF THE *CODASTER ALTERNATUS — CODASTER PYRAMIDATUS* GROUP IN THE DEVONIAN IN THE VICINITY OF LOUISVILLE, KENTUCKY

Series	New York Section	Generalized Section for Southern Indiana and Northern Kentucky[1,2]		Section at Falls of Ohio at Louisville, Kentucky and Clarke Co., Indiana[2]		*Codaster americanus*	*Codaster alternatus*	*Codaster pyramidatus*	*Codaster robustus*
			Fm.	Members	Fm.	Members or Zones				
ERIAN	Hamilton Group: Moscow formation									
	Ludlowville formation		Sellersburg ls.	Beechwood limestone	Sellersburg ls.	Beechwood limestone 4'				X
	Skaneateles formation			Swanville limestone						
				Silver Creek limestone		Silver Creek limestone 15'				
	Marcellus formation			Deputy limestone						
				Speed limestone						
ULSTERIAN	Onondaga limestone	Jeffersonville limestone			Jeffersonville ls.	*Parospirifer acuminatus* zone 10'	X	X	X	?
						Brevispirifer gregarius zone 10'				
	Schoharie shale and ss.	Geneva dolomite				Coral zone 10'				
	Esopus shale									
	Oriskany sandstone									
						Underlying Strata=Niagaran				

[1] From G.A. Cooper, *et al*, 1942
[2] From Guy Campbell, 1942

PALEONTOLOGY

History of Nomenclature and Problems in Taxonomy.—Lyon (1857, pp. 493–495, pl. 5, figs. 3, 3a, 3b) described and figured as *Codaster alternatus* some blastoids that he had obtained from what is now termed the *Paraspirifer acuminatus* zone of the upper part of the Jeffersonville formation (Onondagan) near Louisville, Kentucky. A year later Shumard (1858) described *Codaster pyramidatus* (pp. 238, 239, pl. 9, fig. 1a–e) and *Codaster americanus* (p. 239) from the Devonian of the same area and, as nearly as we can determine, from approximately the same stratigraphic position. Wachsmuth, who studied a collection of nearly forty specimens from Louisville, expressed the opinion (1883, pp. 353, 354) that Lyon's illustrations were based on two species, that only his figure 3a should be identified as *C. alternatus*, and that figures 3 and 3b should be referred to Shumard's species *C. pyramidatus*. He stated further that the former species, as thus restricted, includes both large and small representatives, and he proposed to restrict the species name, *alternatus*, to the smaller ones and to regard the larger specimens as a variety, for which he proposed the new name *elongatus;* but he admitted that these might be only the adults corresponding to the other, smaller specimens. Finally, he referred *C. alternatus* and its variety *elongatus* to his newly erected genus *Heteroschisma*, but retained *C. pyramidatus* in the genus *Codaster*.

Etheridge and Carpenter (1886, p. 267) rejected Wachsmuth's genus *Heteroschisma* as a synonym of *Codaster*, but agreed with Wachsmuth that Lyon had described two species under the name *Codaster alternatus*. They figured as *C. alternatus* var. *elongatus* (pl. 10, figs. 19, 20) a specimen which they had obtained on loan from Wachsmuth, but for want of other specimens with which to make a comparison, they offered no opinion as to whether it is actually a variety of *C. alternatus*.

Bather (1899, p. 3) listed *elongatus* as a variety of *C. alternatus* and expressed the view that the name *alternatus* is probably a misprint for *attenuatus*. Rowley, who followed Bather in regard to this supposed mistake, described and figured several specimens from the Devonian of Ohio and Indiana as *C. attenuatus* Lyon (1902, p. 95, pl. 30, figs. 20, 21; 1903, p. 128, pl. 36, figs. 50, 51), *C. attenuatus* Lyon? (1902, p. 94, pl. 30, figs. 14, 15), and *C. attenuatus* var. *robustus* Rowley (1902, p. 94, pl. 30, figs. 12, 13, 16, 17).

The uncertainty regarding the relationships of the species of the *Codaster alternatus-Codaster pyramidatus* group seems to result largely from the fact that Lyon's description of *C. alternatus* was based on material consisting of more than one species. In order to clear up this confusion we have studied Lyon's types of *C. alternatus* and Shumard's type of *C. pyramidatus* in the United States National Museum and Rowley's types of *C. attenuatus* var. *robustus* in the American Museum of Natural History.

Lyon's syntypes of *C. alternatus* consist of five specimens, two of which clearly are the specimens on which his figures 3a and 3b are based. Because Wachsmuth restricted this name to forms conspecific with the species represented by Lyon's figure 3a, we hereby designate as the lectotype of *Codaster alternatus* that one of Lyon's syntypes from which his figure 3a was drawn, and which is the specimen that we have photographed and reproduced as figures 7–9 of plate 27. One more of Lyon's syntypes is conspecific with the lectotype, and this specimen is designated as a paralectotype. The specimen from which Lyon's figure 3b was drawn we are referring to the species that Rowley described as *C. attenuatus* var. *robustus*. Of Lyon's other two types, one is referable to *C. robustus*, and the other is intermediate between *C. pyramidatus* and *C. robustus*.

Heteroschisma alternatus var. *elongatum* Wachsmuth (1883, footnote, p. 354) is merely the adult form of *Codaster alternatus*, a possibility recognized by Wachsmuth at the time he introduced the name. We have confirmed the synonymy by direct comparison of Lyon's types of *C. alternatus* with a specimen identified by Wachsmuth as *elongatus* and loaned to Etheridge and Carpenter for study and illustration (1886, pl. 10, figs. 19, 20).

Rowley regarded *C. attenuatus* var. *robustus* as a variety of Lyon's species *C. alternatus*. He probably was influenced by Lyon's figure 3b, and, as noted above, we refer the specimen from which this illustra-

1From G.A. Cooper, et al, 1942
2From Guy Campbell, 1942

TABLE 2.—SUMMARY OF CHARACTERS BY WHICH MEMBERS OF *Codaster alternatus—Codaster pyramidatus* GROUP CAN BE DIFFERENTIATED

(All Measurements in Mm.)

Codaster robustus	*Codaster pyramidatus*	*Codaster americanus*	*Codaster alternatus*	Characters
Narrow and Sub-Petaloid	Narrow and Sub-Petaloid	Narrow and Linear	Wide and Petaloid	Ambulacra
1.1/4.0	1.2/4.0	0.8/3.5	1.0/3.0	Ratio of Width of Ambulacra to Width of Sinus
8.5	8.5	8.1	8.7	Calyx Diameter
2.6/8.5	3.0/8.5	2.8/8.1	2.0/8.7	Ratio of Length of Deltoids to Diameter of Calyx
7	7	9	6	Number of Hydrospire Slits
8.5	8.5	8.1	8.7	Calyx Diameter
3.7/5.0	3.1/5.8	4.0/4.3	4.4/4.0	Ratio of Length of Basals to Length of Radial Bodies
10.8	11.1	10.7	10.1	Calyx Height
Pentagonal Sides Inflated	Pentagonal Sides Strongly Concave	Pentagonal Sides Straight	Pentagonal Sides Slightly Concave	Shape of Transverse Section Through Radialia
Sides Inflated	Sides Concave	Sides Slightly Concave	Sides Straight	Lateral View
Rounded	Rounded	Expanded	Truncated	Summit
Barely Discernable	Barely Discernable	Distinct	Prominent	Radio-Deltoid Suture
Very Strong	Strong	Strong	Weak	Ornamentation
Slightly More Prominent Than *C. pyramidatus*	Visible	Barely Visible	Prominent	Visibility of Radialia in Oral View

tion was made to *C. robustus*. This species is not at all similar to *C. alternatus* as restricted by us. It is closely related to *C. pyramidatus*, although we consider it to be a distinct species.

Shumard's original description of *Codaster americanus* (1858, p. 237) was not accompanied by illustrations nor has the species been subsequently figured. Shumard stated that the species is similar to *C. pyramidatus*, "of which it may be merely a strongly marked variety." In our collection there are twelve specimens that can be referred to this species, which is quite distinct from *C. pyramidatus* and the other species in this group.

Summary of specific characters.—Table 2 summarizes the characters by which the species of this group can be differentiated. Further details are given in the specific descriptions.

SYSTEMATIC DESCRIPTIONS

Genus CODASTER M'Coy, 1849

The following generic description is essentially the same as that given by Cline (1944, p. 134) in the last edition of "Index fossils of North America" by Shimer and Shrock.

Calyx conical, acutely pointed below and truncated above, periphery near summit; transverse section pentagonal; basals and radials long, subequal; radials only slightly notched by sinuses, limbs bent inward and forming part of truncated summit; deltoids small, wholly confined to summit; four of them triangular, each bearing a median longitudinal ridge, the fifth without a ridge and pierced by a large oval anus. In *C. pyramidatus*, *C. alternatus*, *C. americanus*, and *C. robustus* the posterior deltoid is represented by two plates, the subdeltoid and superdeltoid, which may be the counterparts of the epideltoids and hypodeltoids observed in some other genera, but as we have not completed our study of these structures in some other species of the genus, we are not certain of the correspondence. In genera having epideltoid and hypodeltoid plates the anus occurs between them, but in the species of *Codaster* mentioned above the anus is bounded aborally by the radials and is enclosed laterally and adorally by a crescent-shaped plate, the subdeltoid (probably the counterpart of the epideltoid), which is separated from the barb-shaped apex (superdeltoid) by a distinct suture. Ambulacra short, petaloid to linear, confined to summit; hydrospires in eight groups, two in each interradius except the posterior one, a variable number of folds (two to ten observed) in each group; spiracles absent, the hydrospires opening externally through elongated slits which penetrate the truncated inner edges of the radial limbs and adjacent portions of deltoids.

CODASTER ALTERNATUS Lyon

Plate 27, figures 3–10, 13, 14

Codaster alternatus LYON, 1857, Kentucky Geol. Surv., vol. 3, pp. 493–495, pl. 5, fig. 3a (but not 3 and 3b); ETHERIDGE and CARPENTER, 1886, Catalogue of the Blastoidea, pp. 33, 138, 265, 267; BATHER, 1889, Genera and species of Blastoidea in the British Museum, p. 3; GRABAU and SHIMER, 1910, North American index fossils, vol. 2, p. 487; BASSLER and MOODEY, 1943, Geol. Soc. America Special Paper 45, p. 214.

Heteroschisma alternatum WACHSMUTH, 1883, Ill. Geol. Survey, vol. 7, p. 353 and footnote, pp. 353–354; ——, 1886, Davenport Acad. Nat. Sci. Proc., vol. 4, p. 84 (footnote).

Heteroschisma alternatum var. *elongatum* WACHSMUTH, 1883, Ill. Geol. Survey, vol. 7, p. 354 (footnote); ——, 1886, Davenport Acad. Nat. Sci. Proc., vol. 4, p. 84 (footnote).

Codaster alternatus var. *elongatus* ETHERIDGE and CARPENTER, 1886, Catalogue of the Blastoidea, pp. 23, 33, 34, 88, 262, 267, pl. 10, figs. 19, 20; BATHER, 1899, Genera and species of Blastoidea in the British Museum, p. 3; BASSLER and MOODEY, 1943, Geol. Soc. America Special Paper 45, p. 214.

Codaster attenuatus? ROWLEY, 1902, in G. K. Greene, Contributions to Indiana palaeontology, vol. 1, pt. 10, p. 94, pl. 30, figs. 14, 15.

Description.—Shape of calyx varying from clavate-pyriform in youth to obpyramidal at maturity. Higher than wide, the height-to-width ratio being about 1.7:1 in young and adolescent forms and decreasing slightly to 1.5:1 in the largest individuals. Base attenuate, slightly truncated. In young forms sides of calyx diverge gradually upward, the angle increasing slightly in lower part of radialia and decreasing again as lower ends of ambulacra are approached; in larger specimens sides of calyx are straight, diverging upward at a constant rate to the lower ends of ambulacra where the radial limbs contract sharply; summit truncated in contrast to the more rounded

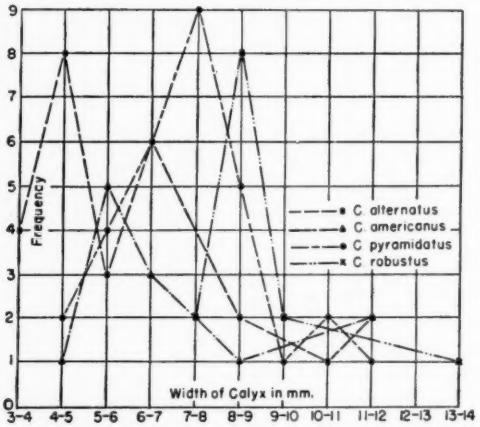


FIG. *1*—Size range and frequency distribution of well preserved specimens of the *Codaster alternatus-Codaster pyramidatus* group.

summit of specimens having a diameter of less than 8 mm. Transverse section pentagonal through radialia, the sides being slightly concave in all but the largest specimens in which they are nearly straight; section triangular through apex of basalia, becoming rounded pentagonal above. Periphery at lower ends of ambulacra.

The average dimensions of 19 measured specimens are: height 8.5 mm., width 5.5 mm., the largest being 15.4 mm. high and 10.6 mm. wide, the smallest 5.1 mm. high and 3.2 mm. wide. Text figure 1 shows the size range and frequency distribution of 26 specimens of *C. alternatus* in which it is possible to measure the width, and similar data are shown for allied species. These graphs obviously show that larger collections are desirable but the shapes of the curves indicate that the average width of adult forms is different in each species. The size range of our specimens is so great that it would be meaningless to give average measurements for plates, ambulacra and other structures. Accordingly, the length of the basals as compared with that of the radial bodies is shown graphically in one of the curves in text figure 2. These curves also bring out the differences in the ratios in *Codaster alternatus* and some allied species. Text figure 3 shows the width of the ambulacra plotted against the width of the radial sinus and shows this curve in comparison with similar curves of other species. Text figure 4 shows the length of the deltoids plotted against the diameter of the calyx and includes curves showing similar data for other species.

Basalia an inverted pyramid, in young forms higher than wide and constricted near apex, but in the largest forms the height and width are about equal, the constriction at the base is less noticeable, and a very slight constriction at the basi-radial suture gives the basalia a slightly inflated lateral profile; the height-to-width ratio is about 1.2:1 in specimens from 7 to 8 mm. high, 1.1:1 in specimens having a height of 12 to 14 mm., and is 9.1:1 in a specimen 15.6 mm. high, which is the second largest specimen in our collection. Basalia constitutes nearly one-half height of calyx in the smaller forms, and only one-third the height of the largest forms: in specimens from 5.1 to 5.3 mm. high the basalia is 2.5 mm. long, in specimens 9.9 mm. high the basalia is 4.1 long. Transverse section circular-pentagonal above, becoming triangular below. Two

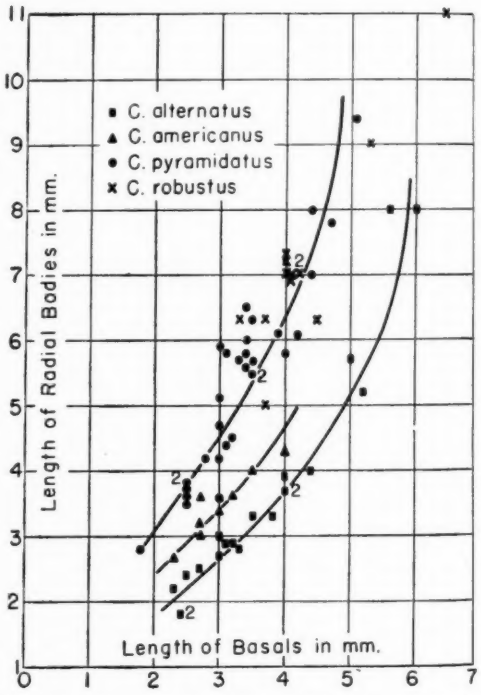


FIG. *2*—Diagram showing relationship of length of basals to length of radial bodies in the *Codaster alternatus-Codaster pyramidatus* group.

basals hexagonal and in contact with radials on three sides; azygos basal smaller, pentagonal, much higher than wide. Basi-radial sutures distinct but not conspicuous. Ornamentation weak.

Radialia expanding upward and attaining greatest width at lower ends of ambulacra. Transverse section through radialia circular-pentagonal below, becoming strongly pentagonal above; sides of pentagon gently concave in young individuals, becoming nearly straight in adult forms. Radials twice as high as wide in large specimens, width increasing gradually upward to maximum at lower end of sinus. Radial limbs bent inward toward mouth, the rate of contraction increasing slightly adorally. Bodies twice as long as limbs (limbs being measured along sides of radial sinus), averaging 2.8 mm. and 1.5 mm. respectively in specimens 7 mm. to 8 mm. high, and 8 mm. and 4.2 mm. in a specimen 15.6 mm. high. Trending lengthwise through midportion of each radial body is a low raised area whose outline is that of a very narrow isosceles triangle wedging out upward at the radial sinus. Radial ornamentation consists of fine lirae parallel to plate margins, being transverse where they cross the raised triangular areas and longitudinal elsewhere. Interradial sutures distinct but not conspicuous.

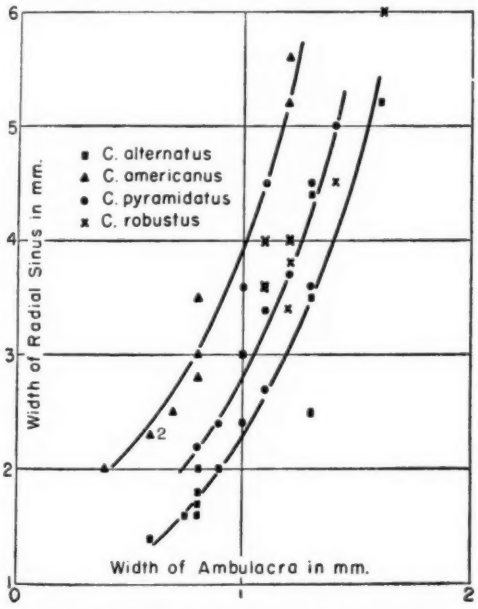


FIG. 3—Diagram showing relationship of width of ambulacra to width of radial sinuses in the *Codaster alternatus-Codaster pyramidatus* group.

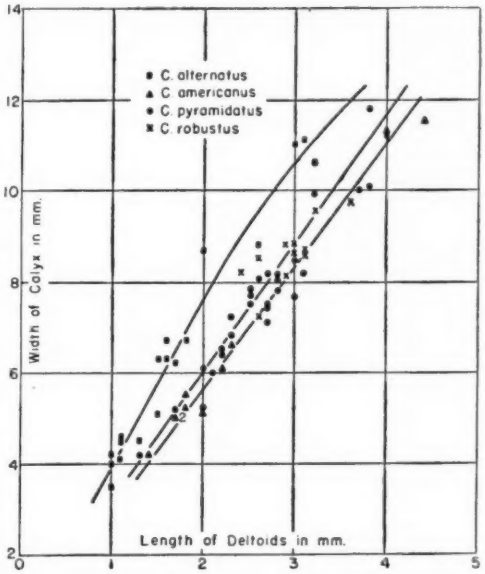


FIG. 4—Diagram showing relationship of length of deltoids to width of calyx in the *Codaster alternatus-Codaster pyramidatus* group.

Deltoids small, barely visible in lateral view, but they and the ambulacra comprise a large portion of the area visible from above. Exposed portion of each deltoid about twice as long as wide, broadly V-shaped aborally where it is bounded by the radio-deltoid suture, sides narrowing gradually adorally but near apex of plate expanding rapidly as the ambulacra suddenly decrease in width, the effect being to produce a blunt spear-shaped apex on each delto'd. Median portion of plate elevated into a narrowly rounded longitudinal ridge which is inclined away from the mouth in young individuals, becomes level at maturity, and is inclined toward the mouth in the largest specimens that we have studied; adorally the ridge passes into a somewhat flattened area that forms the apex of the plate; the apex slopes away from the mouth, is elevated above the ambulacra in young forms, but is slightly depressed below them in the largest forms. Radio-deltoid suture V-shaped, the sides of the V at right angles to

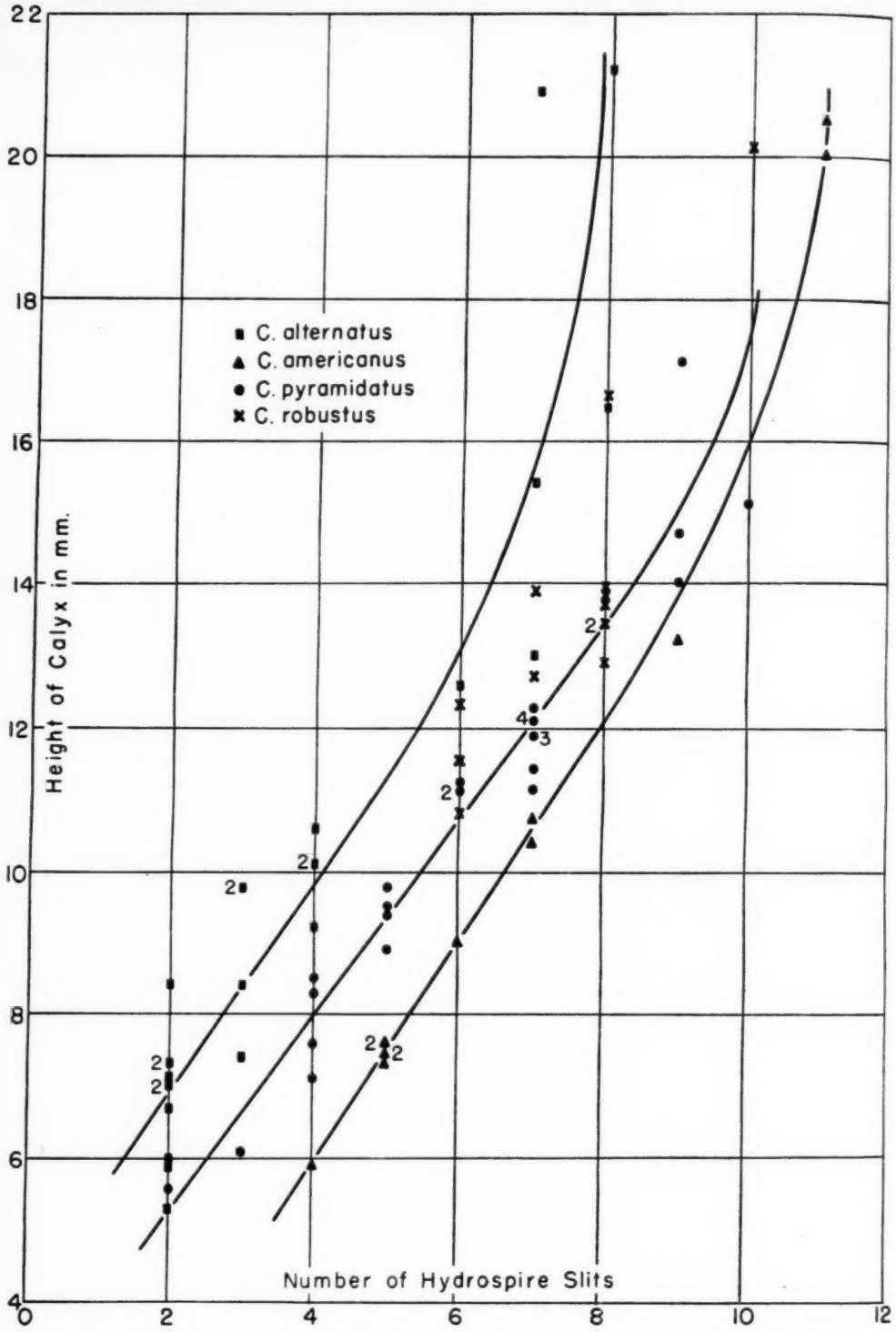


FIG. 5—Diagram showing relationship of number of hydrospire slits to height of calyx in the *Codaster alternatus-Codaster pyramidatus* group.

adjoining ambulacra. Deltoids truncate radial limbs along a surface whose inward slope may in part result from beveling of the radials and overlap by the deltoids. Apex of posterior deltoid similar to others, but aboral portion perforated by the large circular anus. Anus bounded aborally by radial limbs but adoral and lateral portions enclosed by a narrow, slightly raised horseshoe-shaped plate or collar; this plate is separated from the radials by two distinct sutures and is just as clearly set off from the deltoid apex by a curved suture. The plate is presumed to be related to the posterior deltoid rather than to the adjoining radials and possibly should be compared with the epideltoid plates that have been observed in *Schizoblastus* (Wanner, 1924; Cline, 1936), *Brachyschisma*, *Pleuroschisma* and perhaps in *Schizotremites* (Reimann, 1945). In genera in which epideltoid and hypodeltoid plates have heretofore been observed, the plates completely enclose the anus, whereas in *Codaster elongatus*, *C. robustus*, *C. pyramidatus* and *C. americanus* the aboral side of the anus is excavated in the limbs of two adjacent radials.

The name *subdeltoid plate* is proposed for the collar-shaped plate adjacent to the anus, and the name *superdeltoid plate* is suggested for the barbed-shaped adoral component of the anal deltoid region. The superdeltoid is in contact with the subdeltoid, but is separated from it by a suture.

Eight groups of hydrospires, arranged in groups of two in each regular radial interradius, opening externally through elongated slits shared about equally by radials and deltoids; none in the anal interradius. Each group of slits occupies a triangular area on the beveled inner margin of a radial limb and the adjacent aboral and lateral portion of a deltoid. Slits approximately parallel to ambulacra, each slit making an acute angle with its corresponding deltoid ridge. Outer slits very short, becoming progressively longer toward adjacent ambulacrum, the longest slit being about one-half length of ambulacrum. Number of slits increases with the size of the specimen as follows: two to three slits in specimens from 5 to 7 mm. high, three to four where height is 7 to 10 mm., four to five in specimens 10 to 12 mm. high, and five to seven in specimens 12 to 16 mm. high (see text figures 5 and 6). Innermost slit partially concealed by the overhanging side-plates of an ambulacrum.

Ambulacra petaloid in youth, becoming more linear at maturity; width about half

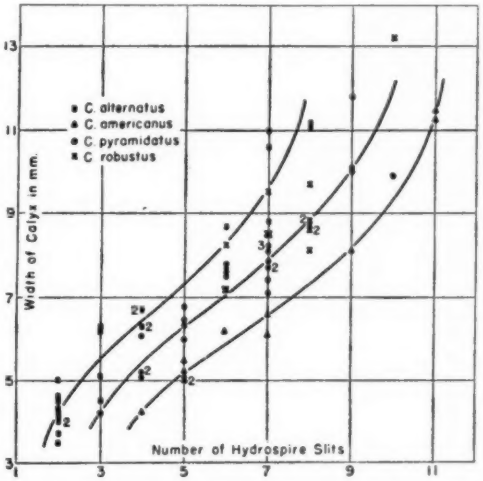


FIG. 6—Diagram showing relationship of number of hydrospire slits to width of calyx in *Codaster alternatus-Codaster pyramidatus* group.

that of sinus in young forms, decreasing to about two-fifths width of sinus at maturity; length about one-third height of calyx in small specimens, about one-half height in largest forms. Lancet completely concealed by side-plates and outer side-plates which are arranged in four vertical rows of about equal width; in specimens 7 mm. high there are about nine side-plates per row and in large forms there are about 20. The two rows of side-plates are separated by the prominent ambulacral groove, and a prominent longitudinal groove likewise separates each row of side-plates from the outer side-plates. Outer edges of outer side-plates deflected upward to produce an elevated ridge, and the two ridges thus formed cause the ambulacrum to be outwardly concave, but this concavity is prominent only in well-preserved specimens. In general the ambulacra are about level with the bordering sinus, but the degree of elevation varies with age of specimen: in young specimens the ambulacra are level with the sinus or elevated slightly above it, but in the largest

forms the highest portion of the deltoid ridge stands somewhat above the ambulacrum.

Remarks.—The five specimens comprising the type material of Lyon's *Codaster alternatus* are in the Springer Collection in the United States National Museum and until recently were cataloged under a single number (S3201). One of the specimens is marked as though it were the holotype, but Lyon did not designate a holotype, nor has any subsequent worker properly done so. Our examination of the types has confirmed Wachsmuth's (1883, pp. 353, 354) published opinion that Lyon's description was based on type material containing more than one species. Wachsmuth restricted the name *C. alternatus* to the species represented by Lyon's figure 3a and he referred Lyon's figures 3a and 3b to Shumard's species *C. pyramidatus*. Lyon's figure 3a is an oral view of the specimen which Springer (or perhaps some other person) marked as the "type," and for the purpose of comparison we have reproduced as figures 8 and 10 of plate 27 Lyon's original illustration alongside our photograph of the so-called type. If the similarity of these figures is not convincing evidence that they represent the same specimen, our examination of the syntypes confirms the point. Lyon's figure 3b was drawn from another syntype; his illustration and our photograph of the specimen are reproduced as figures 6 and 10 of plate 28. Their similarity is quite apparent, and when they are compared with our photographs of Lyon's other syntypes, which are reproduced on this same plate (figs. 16 and 34), there is no doubt about the identity of the specimen represented by Lyon's figure 3b. We cannot determine which specimen was the model for Lyon's "generic figure" (his fig. 3), but we suspect that it was the one from which his figure 3b was drawn.

We cannot agree with Wachsmuth in referring the specimen represented by Lyon's figure 3b to *C. pyramidatus* Shumard. On the contrary, it is conspecific with Rowley's (1902, p. 94, pl. 30, figs. 12, 13, 16, 17) *C. attenuatus* var. *robustus*, to which we assign specific rank.

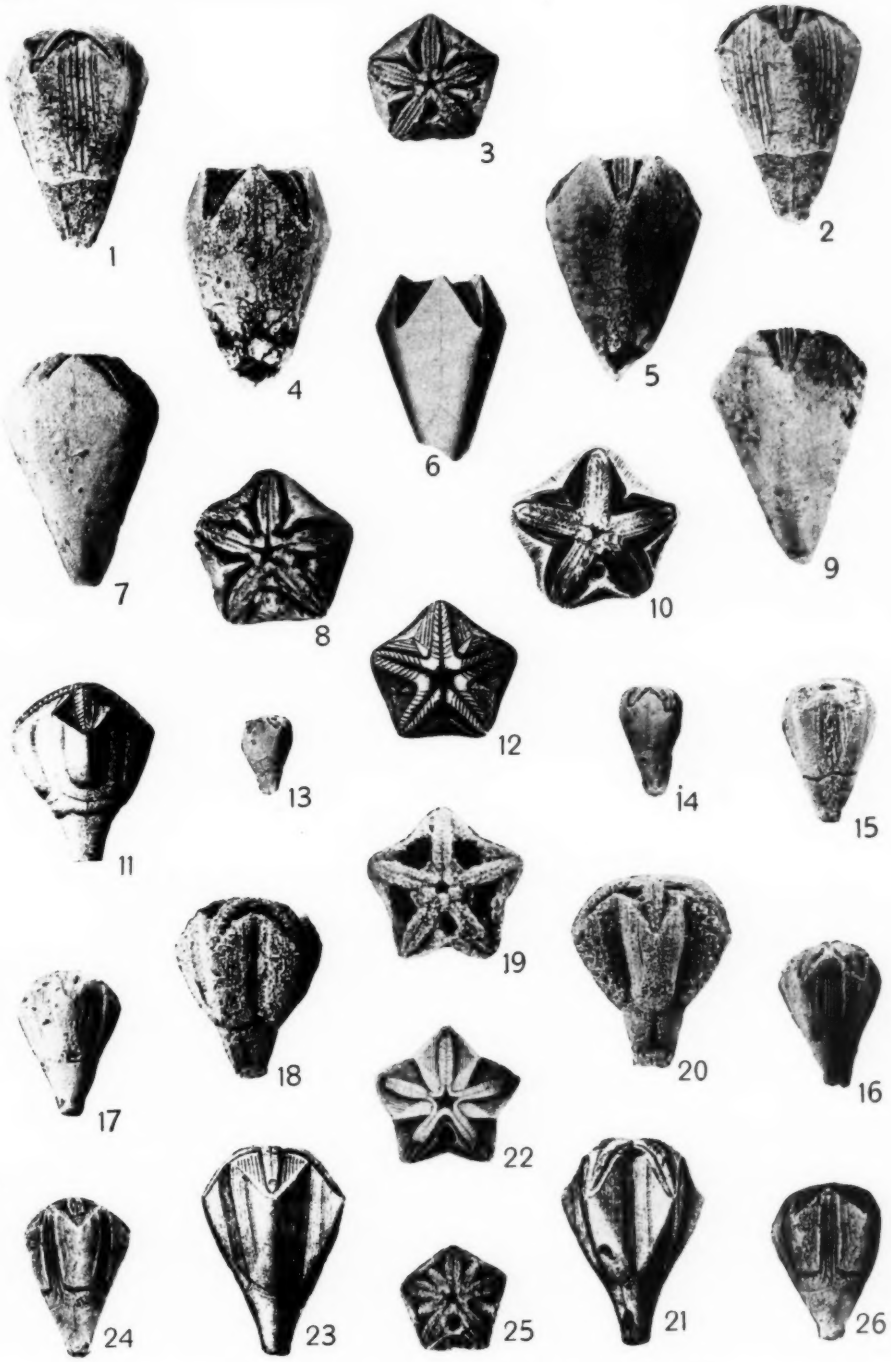
One of Lyon's three remaining syntypes is conspecific with the specimen represented by Lyon's figure 3a, another is conspecific with the specimen represented by Lyon's figure 3b, and the third is intermediate between *C. pyramidatus* and *C. robustus*. Elsewhere in this paper we have designated as the lectotype of *C. alternatus* the specimen from which Lyon drew his figure 3a.

EXPLANATION OF PLATE 27

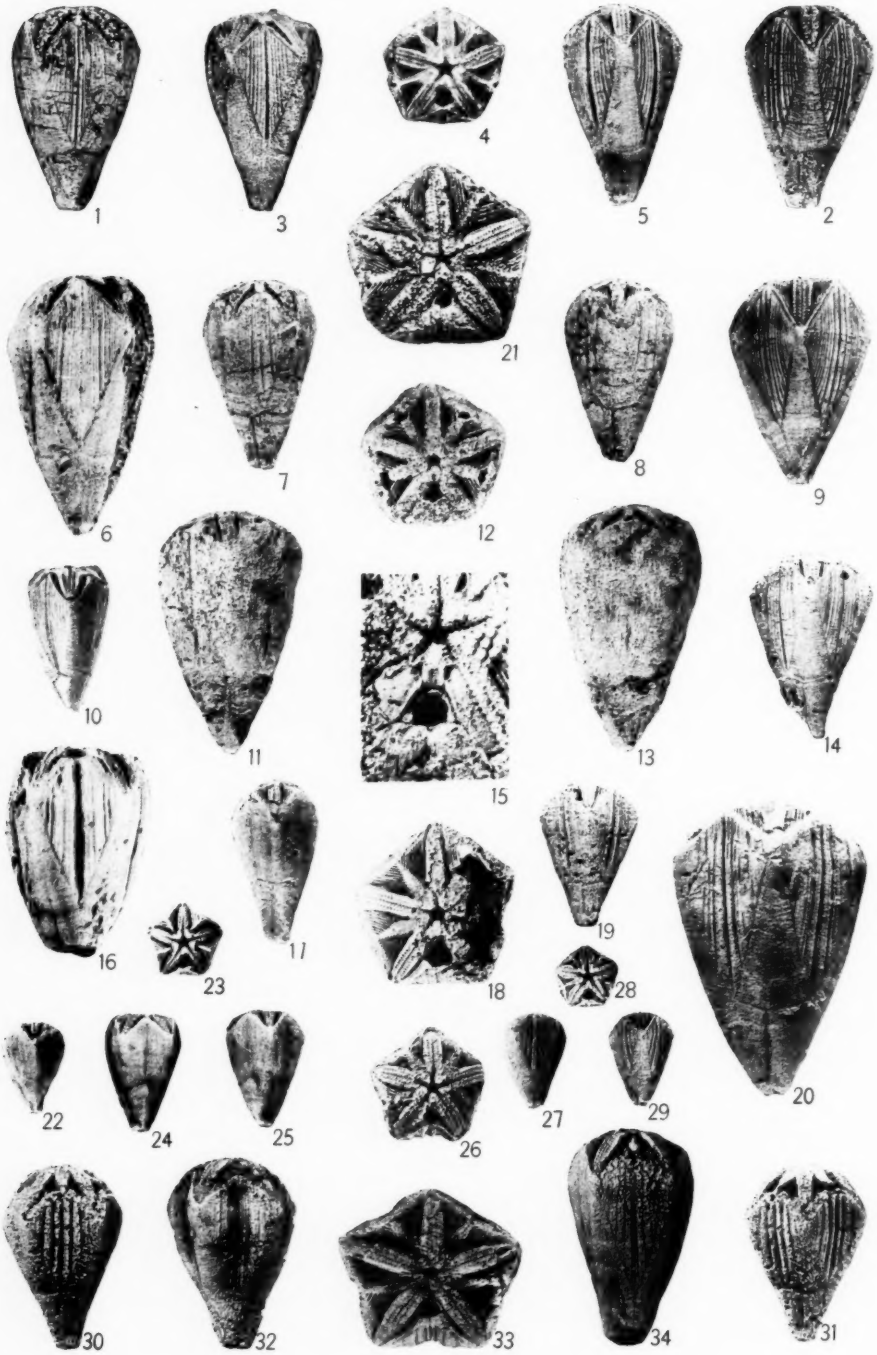
All figures are unretouched photographs except *6*, *10–12*, and *21–23*, which are copied from published illustrations. All figures ×2.

FIGS. *1*, *2*, *11*, *12*, *15–26*—*Codaster pyramidatus* Shumard. Specimens from the Columbus limestone (Onondaga), Columbus, Ohio: *1*, *2*, interradial and radial views of a hypotype (USNM No. (S4592); *15*, posterior interradial view of a hypotype (OSM No. 19852); *16*, *17*, a hypotype (AMNH No. 23794) previously illustrated by Rowley (1902, pl. 30, figs. 22 and 23); *18–20*, an aberrant specimen (a hypotype, AMNH No. 23795) with strongly stellate transverse section and constricted at the basi-radial sutures; this specimen also was illustrated by Rowley (1902, pl. 30, figs. 24, 25). *11*, *12*, Reproductions of Hall's (1862, pl. 1, figs. 12, 13) illustrations of a specimen from the Onondaga near Caledonia, New York (AMNH No. 2975). *21–23*, Reproductions of Etheridge and Carpenter's (1886, pl. 12, figs. 1–3) illustrations of *C. pyramidatus*. *24–26*, The lectotype (USNM No. S3214) of *C. pyramidatus;* from the Jeffersonville limestone, Louisville, Kentucky. (p. 167)

3–10, *13–14*, *Codaster alternatus* Lyon. *3*, A hypotype (USNM No. S3203) from the *Nucleocrinus* subzone of the *Paraspirifer acuminatus* zone of the Jeffersonville formation, near Whirlpool Point, Falls of the Ohio, Clark County, Indiana. *4*, *5*, A hypotype (USNM No. S3207) Jeffersonville formation, Louisville, Kentucky; *6*, this specimen, illustrated by Etheridge and Carpenter (1886, pl. 10, figs. 19, 20) as *C. alternatus* var. *elongatus*, was identified by Wachsmuth as his *Heteroschisma alternatum* var. *elongatum* and loaned to them for study. *7–9*, The lectotype (USNM No. S3201) of *C. alternatus;* from the Jeffersonville formation, Falls of the Ohio, Louisville, Kentucky. *10*, Reproduction of Lyon's (1857, pl. 5) fig. 3a, a drawing obviously based on the specimen that we have designated as the lectotype. *13*, *14*, Two small hypotypes from the Jeffersonville formation at the Falls of the Ohio, Louisville, Kentucky; *13*, an immature specimen 5.1 mm. high (USNM No. S4537); *14*, a slightly larger but youthful specimen 7.5 mm. high (USNM No. S4538). (p. 159)



Cline and Heuer, Mid-Devonian Blastoids



Cline and Heuer, Mid-Devonian Blastoids

Summary of characteristics of Codaster alternatus *and comparison with allied species.*—As exhibited by the lectotype, paralectotype, and numerous topotypes, *C. alternatus* has the following distinguishing characteristics: a pentagonal transverse section with slightly concave sides; young specimens have a slender, rather attenuate base; the basals are relatively long, being longer than the radial bodies in specimens having a diameter of less than 5 mm.; the deltoids are relatively short as compared with the diameter of the calyx, with the result that the upper ends of the radials are prominent in an oral view; the deltoid ridges are narrow and the sides of the deltoids slope rather steeply downward toward the ambulacra; the radio-deltoid suture is easily discernible; and the ornamentation is relatively weak, consisting of fine lirae parallel to the plate margins; the lirae are easily obliterated and are noticeable only in well preserved specimens.

C. alternatus is quite distinct from *C. pyramidatus*, *C. robustus* and *C. americanus* (see table 2). Its ambulacra are wider, more petaloid, and occupy a relatively larger proportion of the width of the sinus, and its deltoid ridges are sharper and slope more steeply toward the ambulacra. It has fewer hydrospire slits (see figs. 5 and 6), the number on either side of an ambulacrum averaging one less than in *C. robustus* and *C. pyramidatus*, and two less than in *C. americanus* in the same size grades. Also, the upper ends of the radials are more prominent when viewed from above. As previously noted, the basals of *C. alternatus* are

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EXPLANATION OF PLATE 28

All figures are ×2 except 10 and 15.

FIGS. *1–13, 20, 21—Codaster robustus* Rowley. *1, 2*, Interradial and radial views of a hypotype (USNM No. S4584) from the Middle Devonian, Clark County, Indiana. *3–6*, Hypotypes from the Middle Devonian, Louisville, Kentucky; *3–5*, interradial, oral and radial views of a single specimen (USNM No. S4574); *6*, photograph of one of Lyon's syntypes (USNM No. S4602) of *C. alternatus;* this is probably the specimen on which his fig. 3b (Lyon, 1857, pl. 5, fig. 3b) was based. (Lyon's fig. 3b is reproduced as our fig. *10* immediately below our fig. *6*.) *7–9*, Two hypotypes from the Middle Devonian, Falls of the Ohio, Louisville, Kentucky; *7, 8*, interradial and radial views of a single specimen (USNM No. S4585); *9*, radial view of a strongly marked specimen (USNM No. S4586). *10*, Reproduction of Lyon's fig. 3b (×1) to show the similarity between it and our fig. 6; both figures are believed to represent the same specimen. *11–13*, Three views of the holotype (AMNH No. 23790) which, according to Rowley, came from strata of Hamilton age (most likely the Beechwood member of the Sellersburg formation), Clark County, Indiana. *20, 21*, A very large hypotype (USNM No. S4573) from the Jeffersonville limestone, Louisville, Kentucky. (p. 170)

14, 15, 19, 26–34—Codaster pyramidatus Shumard. *14, 27–29*, Specimens from the middle Devonian (probably the Jeffersonville formation), Falls of the Ohio, Louisville, Kentucky; *14*, a hypotype (AMNH No. 23796) which was originally figured by Rowley (1902, pl. 30, figs. 20, 21) as *C. attenuatus* (should have been written *C. alternatus*); *27–29*, Three views of a very young individual (a hypotype, USNM No. S4534). *15, 32*, Two specimens from the "Corniferous" (probably from the upper part of the Columbus limestone), Columbus, Ohio; *15*, oral view (×4) of a hypotype (WM No. 19067a) showing the plate structure of the anal region; *32*, interradial view of another hypotype (WM No. 19067c). *19*, Another hypotype (AMNH No. 23793) from the Middle Devonian (probably upper part of Columbus limestone), Columbus, Ohio; this specimen was previously illustrated by Rowley (1902, pl. 30, figs. 18, 19). *26, 30, 31*, Specimens from the Columbus limestone, Columbus, Ohio; *26*, oral view of a hypotype (OSM No. 19853); *30, 31*, a coarsely ornamented hypotype (OSM No. 19854). *33, 34*, Specimens from the Jeffersonville formation in the Louisville, Kentucky, area; *33*, oral view of a large hypotype (USNM No. S4590) from the old Workhouse quarry; *34*, another hypotype (USNM No. S4603) from the Louisville area; this specimen is one of Lyon's syntypes of *C. alternatus*. (p. 167)

16—A specimen intermediate in character between *C. pyramidatus* and *C. robustus;* one of Lyon's syntypes of *C. alternatus* from the Jeffersonville formation, Louisville, Kentucky; now in the United States National Museum (a hypotype, No. S4604). (p. 164)

17, 18, 22–25—Codaster americanus Shumard. All specimens from the Jeffersonville formation in the Louisville area in Kentucky. *17*, A rather attenuate hypotype (USNM No. S4566). *18*, A large hypotype (USNM No. S4598) from Beargrass Creek; diameter of calyx 11.3 mm. *22*, A very young specimen, a hypotype (USNM No. S4567); *23–25*, The neotype of *C. americanus* (USNM No. S4565). (p. 171)

relatively long as compared with the radial bodies; in the three other species the latter are longer than the basals in all growth stages. In the transverse section, the slightly concave sides are in contrast to the straight sides of *C. americanus*, the slightly convex sides of *C. pyramidatus*, and the inflated sides of *C. robustus*. The radio-deltoid sutures are easily seen; they are less distinct in *C. americanus*, and are only barely discernible in certain weathered specimens of *C. pyramidatus* and *C. robustus*. The ornamentation on *C. alternatus* is relatively weak, whereas that of the other species is very pronounced.

Synonymy.—As noted above, Wachsmuth's (1883, footnote p. 354) *Heteroschisma alternatum* var. *elongatum* is the adult form of *Codaster alternatus*. We have ascertained this by comparing Lyon's types with a specimen of *elongatum* identified by Wachsmuth and loaned to Etheridge and Carpenter (1886, pl. 10, figs. 19, 20) for study. Etheridge and Carpenter returned the specimen to Wachsmuth; it became a part of the Springer collection, and is now in the United States National Museum cataloged as S3207. The label which accompanies it identifies the specimen as that figured by Etheridge and Carpenter, and any doubt concerning its identity is dispelled by noting the chipped character of the base. Our photographs of this specimen (figs. 4 and 5 of pl. 27) are shown alongside photographs of the lectotype of *Codaster alternatus* (figs. 7–9) and a copy of the illustration (fig. 6) of Etheridge and Carpenter.

Rowley (1902, 1903) described and illustrated some Devonian blastoids as *C. attenuatus*, *C. attenuatus?* and *C. attenuatus* var. *robustus* in G. K. Greene's "Contributions to Indiana palaeontology." For many years the status of Rowley's specimens has been in doubt because his descriptions are inadequate and his illustrations (drawings reproduced as woodcuts) are unsatisfactory. The whereabouts of Rowley's types has not been generally known, but we recently learned that this collection is in the American Museum of Natural History. We have studied Rowley's material and have found that the only figured specimen that is conspecific with *C. alternatus* is the one that Rowley labeled as doubtfully belonging to that species. Rowley's types of *C. attenuatus* var. *robustus* (Rowley, 1902, pl. 30, figs. 12, 13, 16, 17) clearly are not conspecific with *C. alternatus* and we are describing them elsewhere in this paper as a separate species. The form described and illustrated as *C. attenuatus?* (AMNH No. 23792) clearly is to be referred to *C. alternatus;* the basals are longer than the radial bodies, there are four hydrospire slits on each side of an ambulacrum, as compared to five and six in specimens of *C. pyramidatus* of comparable size, the transverse section is pentagonal with slightly concave sides, the summit is contracted so that the upper ends of the radials are prominent in an oral view, the ambulacra are petaloid, the deltoid ridges are narrow and sharp, the radio-deltoid sutures are prominent, and the calyx is devoid of ornamentation. The specimens from the "Middle Devonian" at the Falls of the Ohio (AMNH No. 23796) which Rowley (1902, pl. 30, figs. 20, 21) described and illustrated as *C. alternatus* we refer to *C. pyramidatus*, along with the specimens from the Middle Devonian at Columbus, Ohio (AMNH No. 23885), which Rowley (1903, p. 128, pl. 36, figs. 50, 51) also identified as *C. pyramidatus*.

Occurrence.—According to the label which accompanies Lyon's types of *C. alternatus* the specimens came from the "Hamilton group, Louisville, Kentucky," but Lyon's original description states that they were collected from earthy partings in limestone eight feet below the hydraulic cement beds and below the *Nucleocrinus* zone at the Falls of the Ohio and in the same geological position on the South Fork of Beargrass Creek, Jefferson County, Kentucky. The hydraulic cement bed is the Silver Creek member of the Sellersburg formation, (Hamilton) and strata eight feet lower are in the *Paraspirifer acuminatus* zone of the Jeffersonville limestone (Onondaga); the *Nucleocrinus* subzone is in the lower portion of this zone. Cataloged under the number S3202 in the United States National Museum are twenty specimens of *Codaster alternatus* that came from the "Onondaga, Falls of the Ohio," probably from the same zone within the Jeffersonville. The United States National Museum collection contains a few additional specimens labeled as coming from the Onondaga on the Indiana

side (Clark County) of the river at the Falls of the Ohio and from the Onondaga in the old Workhouse quarry and along Beargrass Creek in the vicinity of Louisville, Kentucky. Wachsmuth (1883, p. 353) reported his variety *Heteroschisma alternatum* var. *elongatum* (a synonym of *C. alternatus*) as occurring in the lower part of the Hamilton group along with *Heteroschisma* [= *Codaster*] *alternatum*. However, the label on the specimen of *C. elongatus* that Wachsmuth loaned Etheridge and Carpenter (USNM No. S3207), and which they figured, records the beds as Onondagan. Most of the other numerous references in the literature to *C. alternatus* are in faunal lists which cite Lyon, Wachsmuth, or Rowley as the authority for the occurrence, and the other reported occurrences are based on misidentified specimens.

Types.—The lectotype and paralectotype are Nos. S3201 and S4601, respectively, in the United States National Museum; figured hypotypes USNM Nos. S3203, S3207, S4537, and S4538.

CODASTER PYRAMIDATUS Shumard

Plate 27, figures 1, 2, 11, 12, 15–26; plate 28, figures 14, 15, 19, 26–34

Codaster pyramidatus SHUMARD, 1858, St. Louis Acad. Sci. Trans., vol. 1, no. 2, pp. 238, 239, pl. 9, figs. 1a–1e; HALL, 1862, New York State Cabinet Nat. Hist. 15th Ann. Rept., p. 152, pl. 1, figs. 12, 13; ETHERIDGE and CARPENTER, 1882, Ann. and Mag. Nat. Hist., ser 5, vol. 9, pp. 233–235; ——, 1886, Catalogue of the Blastoidea, pp. 266–268, pl. 12, figs. 1–3; ROWLEY, 1902, in: Greene, Contributions to Indiana palaeontology, vol. 1, pt. 10, p. 95, pl. 30, figs. 12, 18, 22–25; GRABAU and SHIMER, 1910, North American index fossils, Invertebrates, vol. 2, p. 487, fig. 1800; CLINE, 1944, in: SHIMER and SHROCK, Index fossils of North America, p. 134, pl. 50, figs. 4, 5.

Codaster attenuatus ROWLEY, 1902, in: Greene, Contributions to Indiana palaeontology, vol. 1, pt. 10, p. 30, figs. 20, 21; ——, 1903; in: Greene, Contributions to Indiana palaeontology, vol. 1, pt. 12, p. 128, pl. 36, figs. 50, 51.

Description.—Calyx obpyriform in small forms, becoming club-shaped in some larger specimens. Basalia slightly truncated, sides diverging upward at about 34 degrees, the angle increasing to 55 or 60 degrees in lower part of radialia, thus producing a slightly concave area bordering the basi-radial suture; average angle of divergence of radialia about 44 degrees; summit convex, contracting rapidly above periphery, which is located at lower ends of ambulacra. Transverse section pentagonal through radialia, nearly circular at basi-radial sutures, becoming triangular through basalia; in large specimens depressed areas bordering the interradial sutures produce a stellate-pentagonal peripheral section.

The average dimensions of 29 specimens are; height 10.8 mm., width 7.2 mm., the largest being 17.1 mm. high and 11.8 mm. wide, the smallest 5.6 mm. high and 4.2 mm. wide (see text figs. 1, 4, 5, and 6); average length of basals in 29 specimens, 3.3 mm., the minumum being 2.3 mm., the maximum 5.1 mm.; average length of radial bodies in 31 specimens, 5.3 mm., the range being from 2.7 mm. to 9.4 mm. (see text fig. 2); average length of deltoids in 26 specimens, 2.6 mm., the range being from 1.3 mm. to 3.8 mm. (see text fig. 4); average length of ambulacra in 15 specimens, 1.1 mm., ranging from a maximum of 1.4 mm. to a minimum of 0.8 mm.

Basalia slightly constricted below, forming approximately one-third the height of the calyx in mature individuals and a proportionately larger part in young ones. Three broadly rounded ridges, two radial in position and one aligned with the right antero-interray, originate on the basalia and pass upward into five ridges on the radialia. Two basals hexagonal and in contact with radials on three sides; azygos basal, smaller and pentagonal. Basi-radial suture distinct, but neither raised nor depressed. Ornamentation not as prominent as that of radialia, but fine transverse lirae have been observed on some specimens.

Radialia higher than wide, expanding upward to height of periphery (lower ends of ambulacra), the rate of expansion decreasing thereabove; radials bent inward above periphery, gradually contracting above. Radials higher than wide, width increasing upward to periphery; bodies long, comprising most of height of radials in side view; limbs comprise but a small part (perhaps one-fifth) of length of each radial measured around outside of plate. Text figure 2 shows the length of radial bodies plotted against length of basals. Bodies two-thirds as wide as high, for example, being 4 mm. wide and 6.5 mm. high in a

specimen 12 mm. high; gently convex outward in longitudinal section, strongly convex in transverse section, the convexity being greatest in the midportion, the sides nearly flat although in many adult forms strongly deflected inward at lateral margins of plates to produce a prominent depressed area in which the interradial sutures lie, thus giving a stellate outline to the transverse section of the radialia. Width and depth of depressed zone varies, but is about 1.5 mm. wide in mature forms. Radial ornamentation consists of fine lirae parallel to lateral and lower margins of plates, which results in a long narrow triangular area with very fine transverse ornamentation, the area decreasing in width upward and corresponding to a raised triangular ridge; larger areas on each side marked with coarser, more widely spaced longitudinal (vertical) lirae, the coarsest bordering the interradial depressions.

Deltoids subtriangular in outline, about three-fourths as wide as long, constricted near apex where ambulacra are widest, but widening again toward mouth, thus giving the apex the shape of a blunt spearhead. Deltoid ridge lanceolate, aboral portion outwardly convex and narrowly rounded, becoming flattened or slightly concave orally; in general, the ridges slope away from the mouth, although in some specimens the outer portion of each is elevated to the level of the apex, producing a concave peristome. Aboral-lateral portions of plates slope gently downward from the oral ridges to the ambulacra, and are pierced by the hydrospire slits. Posterior deltoid divided into subdeltoid and superdeltoid plates, the former being horseshoe-shaped and enclosing the anus on three sides. Adorally the anus adjoins the radials. Radio-deltoid sutures indistinct, straight and approximately at right angles to ambulacra.

Ambulacra narrowly petaloid, their width in young specimens being less than one-third the maximum distance separating adjacent deltoid ridges, but in adults the relative width is somewhat less (see text fig. 3). In most specimens the lower half of the ambulacra are approximately level with the bordering deltoid ridges but the upper portions are elevated above the deltoids, producing a rounded summit, outwardly convex but slightly depressed around mouth. Side-plates and outer side-plates separated by three prominent longitudinal grooves into four distinct rows, the outer ones being widest; in specimens 7 to 9 mm. high there are 12 to 14 plates per row, the number increasing to 18 or 20 in specimens 14 to 15 mm. high.

Two groups of hydrospires in each regular interradius, none in the anal interradius; each group of slits occupies a triangular area shared about equally by the beveled inner margins of a radial limb and an adjacent deltoid. Slits parallel to ambulacra, making an acute angle with deltoid ridges; width of slits about that of intervening ridges; outermost slits short, the others becoming progressively longer toward the ambulacrum; the longest slit in each group about one-half as long as adjacent ambulacrum, partially concealed by it, and the adoral end enlarged to resemble somewhat the spiracles in *Schizoblastus*. An increase in the number of slits in each group corresponds to a size increase (see text figs. 5 and 6); small specimens 6 to 8 mm. high have from three to four slits; the number increases to seven or eight at a height of 12 to 14 mm., and there are nine in a specimen 17 mm. high.

Remarks.—Shumard's description of *C. pyramidatus* (1858, p. 238) obviously was based in part on material obtained on loan, but his illustrations (figs. 1a-e) seem to have been drawn mostly from a single specimen which is now in the Springer Collection in the United States National Museum (No. S3214). The anus is not as large as shown, but otherwise the illustrations are excellent. We hereby designate this specimen as the lectotype of the species.

C. pyramidatus is distinguished from *C. alternatus* and *C. americanus* by the following points of difference. It has more hydrospire slits than *C. alternatus* and fewer than *C. americanus* in all growth stages (see text figs. 5 and 6); the length of the deltoids as compared with the width of the calyx is noticeably greater than in *C. alternatus*, with the result that the deltoids comprise a proportionately larger part of the upper surface (text fig. 4); the width of an ambulacrum as compared with the width of its radial sinus is greater than in *C. americanus* and less than in *C. alternatus* (text fig. 3);

the length of the basals as compared with the length of the radial bodies is less, and the deltoid ridges are broader, flatter, and more lanceolate than in the two other species. In most specimens of *C. pyramidatus* the interradial sutures lie in a depressed zone, which is so deeply impressed in some as to give a stellate outline to a transverse section; the radio-deltoid suture is barely discernible, but is easily distinguished in *C. alternatus;* the ornamentation on the radialia is prominent, whereas it is weak in *C. alternatus;* finally, because the upper ends of the ambulacra are raised above the bordering deltoid ridges, the summit is more rounded than in *C. alternatus* or in *C. americanus.*

C. pyramidatus and *C. robustus* appear to be gradational species, and an examination of text figures 2 to 6 reveals that they have many characteristics in common. In each case the curve that is reproduced represents *C. pyramidatus,* but the corresponding curve for *C. robustus* is quite similar. *C. robustus* is distinguished by having a more inflated, globular basalia, and a more inflated radialia, which results in a circular-pentagonal transverse section as compared with the more decagonal section of *C. pyramidalis.* The radialia in *C. pyramidatus* typically expands upward at a more rapid rate than the basalia, producing a somewhat concave area in the vicinity of the basi-radial sutures, whereas in *C. robustus* the angle of divergence is the same in the radialia and basalia, or perhaps a little less in the radialia. The overall effect of these differences is to produce a more inflated, more robust calyx in *C. robustus.* The ornamentation of this species is also more prominent than that of *C. pyramidatus.*

James Hall (1862, p. 152, pl. 1, figs. 12, 13) illustrated as *C. pyramidatus* a specimen from the "upper Helderberg" [=Onondaga] from near Caledonia. New York, and indicated that it had two basi-radial sutures. He evidently was influenced by Lyon (1857, pp. 468, 469) who believed that some blastoids have two sets of radials. Hambach (1880, pp. 146, 147) denied the existence of an extra circlet of radials as did Etheridge and Carpenter (1886, p. 20). We have recently examined Hall's figured specimen (No. 2975 AMNH) and can now understand why Hall was misled; the specimen is an internal mold, weathered in such a manner that one can easily imagine an extra set of sutures. Although the specimen is poorly preserved, we have no reason to doubt that it represents *C. pyramidatus.*

In 1902 Rowley referred to *C. pyramidatus* three blastoids that came from Middle Devonian (probably the Columbus limestone) strata near Columbus, Ohio. Our examination of these specimens, now in the American Museum of Natural History, shows that two (Nos. 23793 and 23794 AMNH) which were illustrated as figures 18, 19, 22, 23 of plate 30 are typical representatives of the species, but the other (No. 23795 AMNH) represented by figures 24 and 25 on the same plate has an exceptionally stellate transverse section and the calyx expands rapidly above the basi-radial suture (see figs. 18–20, pl. 1).

Another specimen in the American Museum of Natural History (No. 23796) that was figured and described by Rowley (1902, pl. 30, figs. 20, 21) as *C. attenuatus* we are referring to *C. pyramidatus* on the basis of the following characteristics: the basals are shorter than the radial bodies; there are seven hydrospire slits, one more than in similar sized specimens of *C. alternatus;* the interradial sutures are in depressed areas; the radials are barely visible in an oral view; ornamentation is strongly developed; and the deltoid ridges are broad and lanceolate rather than narrow. This specimen is from the Onondaga at the Falls of the Ohio. Another specimen (AMNH No. 23885) identified by Rowley (1903) as *C. attenuatus* and illustrated as figures 50 and 51 of his plate 36, is just as clearly *C. pyramidatus.* This specimen is from the Onondaga at Columbus, Ohio.

Occurrence.—Codaster pyramidatus seems to be confined to rocks of Onandaga age, Shumard's original publication reports the species as occurring in the "Devonian" at the Falls of the Ohio and on Beargrass Creek at Louisville, Kentucky, and from Columbus, Ohio. One of his types, now in the United States National Museum, was labeled as Onondagan, perhaps by Shumard or Springer. Butts (1915, p. 110) listed this species from the Jeffersonville limestone (Onondagan) of Kentucky, but did not include it in the fauna of the overlying rocks

of Hamilton age. It was reported by Stauffer (1909, p. 32) to be a common fossil in zone H at the top of the Columbus limestone (Onondagan) of Ohio. In collections in the American Museum of Natural History, United States National Museum, Walker Museum, and Ohio State University, we have seen numerous examples of this species labeled as being from the Columbus limestone from near Columbus, Ohio. Stauffer (1915, pp. 81, 127) has reported the species from the Onondaga of southwestern Ontario: and Clarke and Luther (1904, p. 43) listed it from the Onondaga of New York. Hall (1862, p. 152, pl. 1, figs. 12, 13) reported it from the upper Helderberg near Caledonia, New York, but Dr. Rousseau H. Flower has written us that these strata are now regarded as Onondaga.

Types.—Lectotypes, USNM No. S3214. Figured hypotypes, USNM Nos. S4590. S4534, S4592, S4603, AMNH Nos. 23793–23796; OSM Nos. 19852–19854; WM Nos. 19067a, 19067c.

CODASTER ROBUSTUS Rowley
Plate 28, figures 1–13, 20, 21

Codaster alternatus LYON, 1857, Kentucky Geol. Survey, vol. 3, pl. 5, fig. 3b (but not 3 and 3a).
Codaster attenuatus var. *robustus* ROWLEY, 1902, in: Greene, Contributions to Indiana palaeontology, vol. 1, pt. 10, p. 94, pl. 30, figs. 12, 13, 16, 17.

Description.—This species is so similar to *Codaster pyramidatus*, described above, that rather than give a detailed description, only essential differences from *C. pyramidatus* will be emphasized.

Dimensions approximate those of *C. pyramidatus* except that our collection does not contain small representatives of *C. robustus*.

Calyx more inflated than in *C. pyramidatus* and therefore tending to be more obconical than obpyramidal. Transverse section triangular at base becoming pentagonal-circular at periphery which coincides with lower ends of ambulacra. Basalia inflated, the sides diverging more rapidly than the sides of the radialia, thus producing a convex area in the vicinity of the basiradial sutures in contrast to the concave zone in many specimens of *C. pyramidatus*. Interradial areas convex outward, each ornamented with a prominent diamond-shaped area on which there are rather coarse longitudinal (vertical) lirae; interradial sutures level with plates or slightly depressed but they typically are not as deeply impressed as in *C. pyramidatus*. A low, rounded, narrowly triangular raised outline extends along the midportion of each radial limb, wedges out upward at the sinus, and is ornamented with fine transverse lirae; these ridges and the diamond-shaped interradial area are more prominent than in *C. pyramidatus*.

Remarks.—Rowley (1902, p. 94, pl. 30, figs. 12, 13, 16, 17) originally described this species as *Codaster attenuatus* var. *robustus*, following Bather's (1899, p. 3) suggestion that Lyon (1857, pp. 493–495) had intended his species *C. alternatus* to be termed *C. attenuatus*. *C. robustus* cannot be regarded as a variety of *C. alternatus;* in fact, the relationship is not close enough to warrant a comparison. *C. robustus* and *C. pyramidatus* appear to be gradational species, but we prefer to regard *C. robustus* as a distinct species rather than as a variety of *C. pyramidatus*. The inflated, more robust calyx of *C. robustus*, the more nearly circular transverse section, stronger ornamentation, and the convex lateral profile (in contrast to the slightly concave lateral profile of *C. pyramidatus*) serve to characterize this species.

Occurrence.—According to Rowley's handwritten label, the holotype came from strata of Hamilton age in the old Clark County Cement Quarry, Clark County, Indiana. In a letter dated March 12, 1948, Mr. Guy Campbell of Corydon, Indiana has informed us that the quarry to which Rowley referred is probably the same as Siebenthal's (1901, pp. 383, 384) Clark County Mill Quarry at Sellersburg, Indiana. Siebenthal described 14 feet of "cement rock" below the New Albany black shale. According to Mr. Campbell the lower 10 feet of the "cement rock" is Silver Creek and the overlying four feet is Beechwood, both members of the Sellersburg formation (Hamilton). The blastoid probably came from the Beechwood because the Silver Creek is not known to have produced any blastoids, whereas the Beechwood is highly crinoidal. Rowley (1902, pl. 30, figs. 16, 17) figured another specimen that he doubtfully referred to *C. robustus* and we have compared this specimen with Rowley's holotype

and found them to be conspecific. According to Rowley's label, this specimen was collected from a cut along a streetcar line between Baxter Avenue and Clifton Street in Louisville, Kentucky. The label indicates that it came from Hamilton strata and our opinion is that it is probably from the Beechwood member of the Sellersburg. Thus it seems that both of Rowley's specimens came from strata of Hamilton age. In the University of Iowa collection, cataloged under the number 3-268 and labeled "*Codaster attenuatus*," there are two specimens belonging to to this species that Springer collected from the Hamilton of Clark County, Indiana. In the Springer Collection in the United States National Museum there are numerous representatives of this species cataloged under the number S3202 and labeled as coming from the "upper Helderberg" at the Falls of the Ohio, Louisville, Kentucky. Because the early collections frequently included both Onondaga and Hamilton species, and because the only accurately located representatives of *C. robustus* came from the Beechwood, we are inclined to the view that the species is restricted to strata of Hamilton age.

Types.—Rowley's holotype is No. 23790 in the American Museum of Natural History, and the specimen that he questionably referred to this species and illustrated in figures 16 and 17 of his plate 30 is No. 23791 in the American Museum. Figured hypotypes, USNM Nos. S4573, S4574, S4584–S4586, S4602.

CODASTER AMERICANUS Shumard
Plate 28, figures 17, 18, 22–25

Codaster americanus SHUMARD, 1858, St. Louis Acad. Sci. Trans., vol. 1, no. 2, pp. 239, 247; ——, 1866, St. Louis Acad. Sci. Trans., vol. 2, p. 359.

Description.—Calyx subglobose in very young specimens, becoming obconical at adolescence and obpyramidal at maturity. Height-to-width ratio 1.5:1 in young forms; ratio unknown in largest forms because of incomplete preservation. In lateral profile the base is strongly convex outward, the rate of expansion decreasing rapidly upward to the basi-radial sutures, and then decreasing more gradually through the radialia to the periphery, which coincides with the lower ends of the ambulacra. Section triangular in lower part of basalia, becoming subcircular near basi-radial sutures, and strongly pentagonal, with very straight sides, in upper portion of radialia.

Text figure 1 shows the size grade distribution of twelve of the fourteen representatives of *C. americanus* in the collection we are studying. The shape of the graph indicates that most of the specimens represent youthful forms, and emphasizes the need for additional collecting. Plate proportions and certain other measurements are shown diagrammatically in text figures 2 to 6. Unfortunately the base is not preserved in the two largest specimens.

Basalia strongly inflated, obpyramidal to obconical, slightly constricted near apex; wider than long in young individuals, unknown in the largest specimens; height less than one-half that of calyx, this ratio averaging 0.44:1 in small but well preserved specimens. Sides expand upward at a slightly decreasing rate. Section roundly triangular below, becoming circular-pentagonal above. Two basals hexagonal, about as high as wide, the third pentagonal and higher than wide. Basi-radial sutures distinct.

Radialia expanding gradually upward to lower ends of ambulacra, contracting only slightly above, so that the radial bodies are only barely visible in an oral view. Transverse section strongly pentagonal with very straight sides. Radials nearly twice as high as wide, the sides being nearly parallel; limbs short; bodies long, higher than wide. Interradial sutures prominent, flush with plate margins.

Deltoids relatively large as compared to those of allied species, and, together with the ambulacra, comprise most of upper surface; length of deltoids one and one-half times their width. In outline the apex of each plate is barbed-shaped, the aboral portion V-shaped and bounded by an inconspicuous radio-deltoid suture. Deltoids rest upon and overlap the beveled upper edges of the radials. Midportion of each plate elevated into a prominent, narrowly rounded longitudinal ridge whose outer portion is gently convex in longitudinal profile (the axis of the plate being nearly horizontal or sloping slightly away from the mouth) and whose inner portion (apex) is strongly upturned to form a conspicuous elevation

above the mouth. Aboral portion of posterior deltoid largely occupied by the large circular-pentagonal anus. Aboral portion of anus bounded by radial limbs, but adoral and lateral portions enclosed by subdeltoid. Posterior deltoid appears to be differentiated into subdeltoid and superdeltoid plates, although the suture is not very distinct in our few specimens.

Each group of hydrospire slits occupies a triangular area on the beveled inner margin of a radial limb and the adjacent portion of a deltoid and is about equally divided between radials and deltoids. Slits nearly parallel to ambulacra; outermost slit very short, innermost somewhat more than half as long as ambulacrum; slits about as wide as intervening ridges. Number of slits increasing with size of specimen as follows: four to five slits in a specimen 4.2 mm. wide, five slits in those measuring from 5 mm. to 5.5 mm., seven at a width of 6 mm., nine at 8 mm., and 11 in specimens reaching 11 mm. to 11.3 mm. (see text figs. 5 and 6).

Ambulacra linear; midportion of each deeply depressed below bordering oral ridges, lower ends about level with ridges, upper ends elevated somewhat above the mouth. Width of ambulacrum approximately one-fourth that of sinus, the measurements being 0.6 mm. and 2.3 mm. respectively in a specimen 5 mm. wide, and 1 mm. and 4.6 mm. in a specimen 11.5 mm. wide; text-figure 3 shows graphically how this ratio changes with increasing size. Side-plates and outer side-plates about equal in size; from seven to eight side-plates per row in a specimen 6 mm. high, ten in a specimen 7.5 mm. high, and 18 in a specimen 10.7 mm. high (there are 22 in the largest form in our collection, a broken specimen whose height cannot be determined).

Mouth small, pentagonal; inner edges of enclosing deltoids deflected sharply upward producing an elevated border that in young individuals rises distinctly above the adjacent ends of the ambulacra, but the relative degree of elevation decreases in adult forms. Anus slightly larger than mouth, slightly rhombic in outline; bounded adorally and laterally by the collar-like subdeltoid and aborally by radials.

Remarks.—The exact status of *Codaster americanus* Shumard has been in doubt because it has never been illustrated and because Shumard himself noted that it might be a variety of his species *C. pyramidatus*. According to Shumard, the principal differences are in the much finer striae that ornament the plates of *C. americanus*, the absence of a depressed area bordering the interradial sutures, and the shorter radials.

From Shumard's description Etheridge and Carpenter (1886, p. 265) concluded that *C. americanus* is probably a variety of *C. pyramidatus*, and Bather (1899, p. 3) held the same opinion. *C. americanus* has been cited in the literature by Lyon and Casseday (1860, p. 289), Etheridge and Carpenter (1882, p. 235; 1886, p. 265), Bather (1899, p. 3), Hambach (1903, p. 48), Butts (1915, p. 110), and perhaps others. From these numerous references one might suppose that the status of *C. americanus* is well known. Probably, however, no person subsequent to Shumard has knowingly studied a representative of this species, and the authority for each citation appears to be some previous reference, which directly or indirectly derives from Shumard's original description, which was based on a single specimen whose summit was incompletely preserved. We have 14 specimens of the species, and it is on these that our revised description is based.

The size range of the specimens indicates that size is not a criterion by which *C. americanus* can be separated from *C. pyramidatus*, although Shumard refers to it as "this little species." The lateral profile of *C. americanus* tends to be convex outward, whereas *C. pyramidatus* tends to be somewhat concave in the region of the basi-radial sutures. A transverse section through the radialia of *C. americanus* is pentagonal with straight sides; in *C. pyramidatus* the sides are slightly to strongly concave, a result of the depressed areas bordering the interradial sutures. Text figure 2, in which the length of the basals is plotted against the length of the radial bodies, shows that the basals of *C. americanus* are relatively somewhat longer than in *C. pyramidatus*. One of the distinguishing characters of *C. americanus* is the narrowness of the ambulacra as compared to the width of the sinus; text figure 3 shows that the ambulacra of *C. americanus*

occupy a proportionately smaller part of the sinus width than in allied species. Text figures 5 and 6 show that this species has proportionately more slits than similar sized specimens of *C. pyramidatus*.

Occurrence.—All specimens known to us that are referable to this species seem to have come from the Jeffersonville formation of Onondaga age in the Louisville, Kentucky area. Shumard's (1866, p. 359) type specimen was recorded from the "upper Helderberg" at the Falls of the Ohio, which is an older designation for strata now termed Jeffersonville and known to be of Onondaga age. Thirteen of the fourteen specimens before us bear the label Onondaga, Falls of the Ohio, Louisville, Kentucky and the other specimen came from Onondaga strata on Beargrass Creek in Louisville.

Types.—The whereabouts of Shumard's holotype is unknown. We are designating as the neotype a specimen from the Onondaga (Jeffersonville) at the Falls of the Ohio, Louisville, Kentucky (USNM No. S 4565). Hypotypes used in extending the knowledge of the species are Nos. S4566, S4567, and S4598 USNM.

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GOSPORT EOCENE OSTRACODA FROM LITTLE STAVE CREEK, ALABAMA[1]

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ABSTRACT—Twenty-four species of ostracods, eleven new, and one new genus are described and figured. The material was collected from the Gosport sand of the Claiborne Eocene at Little Stave Creek, Clarke County, Alabama. Mention is made of the known occurrence of any of these species in the Gosport formation at Claiborne Bluff on the Alabama River.

INTRODUCTION

THE outcrop of the Gosport formation at Little Stave Creek,[2] Clarke County, Alabama, is about twenty feet thick, composed almost entirely of coarse green glauconitic or brown ferruginous sand. Parts of it are very fossiliferous and the *Periarchus lyelli* and *Venericardia alticostata* beds are easily recognizable. By comparison, however, the micro-fossils appear to be scarce, but this is only because of the very sandy nature of the formation.

The Gosport sand contains a distinctive ostracod fauna. More species, however, are shared with the overlying Moodys Branch marl, of Jackson Eocene age, than with the the Claiborne Eocene formations of Texas and Louisiana.

The author wishes to thank Dr. Henry V. Howe for the use of specimens from his personal collection, for free access to the entire type collection, and for valuable guidance and criticism. Thanks are also extended to Dr. Grover E. Murray of Louisiana State University for generously supplying his Claiborne Bluff collection for my use in this report. Louis L. McCormick kindly assisted in collecting samples from the Little Stave Creek locality.

[1] Based on a thesis submitted to the Graduate Faculty of Louisiana State University in partial fulfillment of requirements of the Master of Science degree.

[2] For a detailed section at Little Stave Creek, see Smith, R. H. in the Southeastern Geological Society Field Trip Guide Book, June, 1944. With some changes, this section appears in Bandy, O. L., 1949, Bull. Am. Paleontology, vol. 32, no 131, map opposite p. 6, columnar section opposite p. 8.

The type specimens from which the descriptions and figures were made have been deposited in the Henry V. Howe collection, Louisiana State University, Baton Rouge, Louisiana.

Dimensions of figured specimen.—Length, 0.68 mm.; height, 0.38 mm.; width, 0.23 mm.

SYSTEMATIC DESCRIPTIONS

Order OSTRACODA Latreille, 1801
Suborder PLATYCOPA Sars, 1865
Family CYTHERELLIDAE Sars, 1865
Genus CYTHERELLA Jones, 1849
CYTHERELLA sp.
Plate 29, figures 19, 27

Cytherellas occur rather commonly in the Gosport sand at Little Stave Creek and at Claiborne Bluff, Alabama. They may be separated into two groups according to shape, one ovate in outline, the other subquadrate. Because of the great similarity of the Cytherellas of different Tertiary localities it seems inadvisable to assign specific designation to the Gosport specimens.

Suborder PODOCOPA Sars, 1866
Family BAIRDIIDAE Sars, 1887
Genus BAIRDIA M'Coy, 1844
BAIRDIA GOSPORTENSIS Blake, n. sp.
Plate 29, figures 5, 6

Description.—Carapace moderately high in side view, subrhomboidal, highest just anterior to the middle. Left valve larger than right with apparent overlap on ventral margin. Dorsal margin broadly arched, anterior part nearly straight; gently angled at ends of hinge; posterior part tapers in a smooth curve, slightly convex, to a narrowly

rounded postero-ventral end. Posterior of right valve slightly concave above end. Anterior end broadly and obliquely rounded below dorsal slope, bearing several short blunt spines. Ventral margin slightly convex in left valve, somewhat concave in right valve, smooth, except for postero-ventral margin which is spinose. Shell wall smooth, covered with uniformly fine, closely spaced pits. Just below center of carapace a circular cluster of about eight dark muscle scars is visible through the shell wall. Viewed from the inside, valves are moderately deep. Hinge of left valve bears a narrow low bar, separated from dorsal margin by an incised line. Hinge of right valve carries a narrow groove near dorsal margin.

Dimensions of figured specimens.—Length (right valve), 0.70 mm.; height, 0.35 mm. Length (left valve), 0.68 mm.; height, 0.38 mm.

Genus BAIRDOPPILATA Coryell, Sample and Jennings, 1935

BAIRDOPPILATA sp.
Plate 29, figures 1, 2

A species of *Bairdoppilata* occurs in the Gosport sand at Little Stave Creek and at Claiborne Bluff, Alabama, but because only a few valves were found, it seems inadvisable to attempt to describe this form, especially because there is great resemblance between many of the species of this genus in various formations. The Gosport species is figured as a matter of record.

Dimensions of figured specimen.—Length, 0.75 mm.; height, 0.48 mm.

Family CYTHERIDAE Baird, 1850
Subfamily CYTHERIDEINAE Sars, 1925
Genus CLITHROCYTHERIDEA Stephenson, 1936

CLITHROCYTHERIDEA GRIGSBYI (Howe and Chambers)
Plate 29, figures 13–15

Cytheridea grigsbyi HOWE and CHAMBERS, 1936, Louisiana Dept. Cons. Geol. Bull. 5, p. 15, pl. 1, figs. 2, 3; pl. 2, figs. 8, 10, 17, 18; pl. 6, fig. 1.
Cytheridea (*Clithocytheridea*) [sic] *?grigsbyi* VAN DEN BOLD, 1946, p. 80, pl. 7, fig. 15.

Description.—The surface of the carapace appears smooth, but actually is covered with fine pits, so aligned on the ventral margin as to produce a distinct ribbing, a feature which is also common on many specimens from Jackson Eocene localities.

This species is very common in the Gosport sand at Little Stave Creek and at Claiborne Bluff, Alabama.

Dimensions of figured specimens.—Length (right valve), 0.73 mm.; height, 0.38 mm. Length (female left valve), 0.77 mm.; height, 0.45 mm.

CLITHROCYTHERIDEA GARRETTI (Howe and Chambers)
Plate 29, figures 9–11

Cytheridea? garretti HOWE and CHAMBERS, 1935, Louisiana Dept. Cons. Geol. Bull. 5, p. 14, pl. 1, figs. 4, 5; pl. 2, figs. 11, 12; pl. 6, figs. 10, 11.
Cytheridea (*Clithrocytheridea*) *garretti* STEPHENSON, 1936, Jour. Paleontology, vol. 10, p. 702, pl. 94, figs. 5, 6, 10, text figs. 1-l, o, p.
Cytheridea (*Clithrocytheridea*) *garretti*, STEPHENSON, 1942, *idem*, vol. 16, p. 110, pl. 18, fig. 1.
Clithrocytheridea garretti STEPHENSON, 1944, *idem*, vol. 18, p. 449, pl. 76, fig. 1; ——, 1946, *idem*, vol. 20, p. 327, pl. 42, fig. 18.

This species is very common in the Gosport sand at Little Stave Creek and Claiborne Bluff, Alabama. The occurrence of short spines on the ventral margins of some specimens is not considered a sufficiently constant characteristic to justify separation on that basis.

Dimensions of figured specimens.—Length (right valve), 0.72 mm.; height, 0.33 mm. Length (male right valve), 0.61 mm.; height, 0.31 mm. Length (left valve), 0.71 mm.; height, 0.35 mm.

CLITHROCYTHERIDEA CALDWELLENSIS (Howe and Chambers)
Plate 29, figure 12

Cytheridea? caldwellensis HOWE and CHAMBERS, 1935, Louisiana Dept. Cons. Geol. Bull. 5, p. 11, pl. 1, fig. 7; pl. 2, figs. 4–6.
Cytheridea (*Clithrocytheridea*) *caldwellensis* STEPHENSON, 1937, Jour. Paleontology, vol. 11, p. 154, pl. 26, fig. 13.
Clithrocytheridea caldwellensis STEPHENSON, 1946, *idem*, vol. 20, p. 327, pl. 42, fig. 13.

This species occurs sparingly at Little Stave Creek and Claiborne Bluff, Alabama. *C. gosportensis* Stephenson 1942 is a similar form, but has a much more acute postero-ventral angle.

Dimensions of figured specimen.—Length, 0.58 mm.; height, 0.29 mm.

Genus HAPLOCYTHERIDEA Stephenson, 1936

HAPLOCYTHERIDEA MONTGOMERYENSIS (Howe and Chambers)

Plate 29, figure 16

Cytheridea montgomeryensis HOWE and CHAMBERS, 1935, Louisiana Dept. Cons. Geol. Bull. 5, p. 17, pl. 1, fig. 1; pl. 2, figs. 1–3, 7, 9; pl. 6, figs. 17, 18.

Cytheridea (Haplocytheridea) montgomeryensis STEPHENSON, 1936, Jour. Paleontology, vol. 10, p. 700, pl. 94, figs. 3, 4, 9; text figs. 1-g, 1-h, 1-j, 1-k; ——, 1937, *idem*, vol. 11, p. 153; ——, 1942, *idem*, vol. 16, p. 109, pl. 18, figs. 17, 18.

Cytheridea montgomeryensis, BERGQUIST, 1942, Mississippi Geol. Surv. Bull. 49, p. 106, pl. 11, fig. 5.

Haplocytheridea montgomeryensis STEPHENSON, 1946, Jour. Paleontology, vol. 20, p. 322, pl. 42, fig. 29.

This is a common Gosport species at Little Stave Creek and Claiborne Bluff, Alabama.

Dimensions of figured specimen.—Length, 0.70 mm.; height, 0.45 mm.

HAPLOCYTHERIDEA GOOCHI Stephenson

Plate 29, figures 17, 18

Cytheridea (Haplocytheridea) goochi STEPHENSON, 1942, Jour. Paleontology, vol. 16, p. 106, pl. 18, figs. 9, 10.

This a common Gosport species at Little Stave Creek and at Claiborne Bluff, Alabama.

Dimensions of figured specimens.—Length (right valve), 0.56 mm.; height, 0.32 mm. Length (left valve), 0.55 mm.; height, 0.32 mm.

Genus PARACYTHERIDEA G. W. Müller, 1894

PARACYTHERIDEA BELHAVENENSIS Howe and Chambers

Plate 29, figures 3, 4

Paracytheridea belhavenensis HOWE and CHAMBERS, 1935, Louisiana Dept. Cons. Geol. Bull. 5, p. 18, pl. 5, fig. 9.

Paracytheridea palmerae STEPHENSON, 1946 (not VAN DEN BOLD, 1946), Jour. Paleontology, vol. 20, p. 319, pl. 42, fig. 14; pl. 44, fig. 19.

Paracytheridea bastropensis STEPHENSON, 1947, Jour. Paleontology, vol. 21, p. 579.

A comparison of the holotype of *P. bastropensis* Stephenson, formerly *P. palmerae* Stephenson (not Van den Bold, 1946) with the cotypes of *P. belhavenensis* Howe and Chambers reveals that separation is not practicable by means of the criteria suggested by Stephenson. The two are apparently identical.

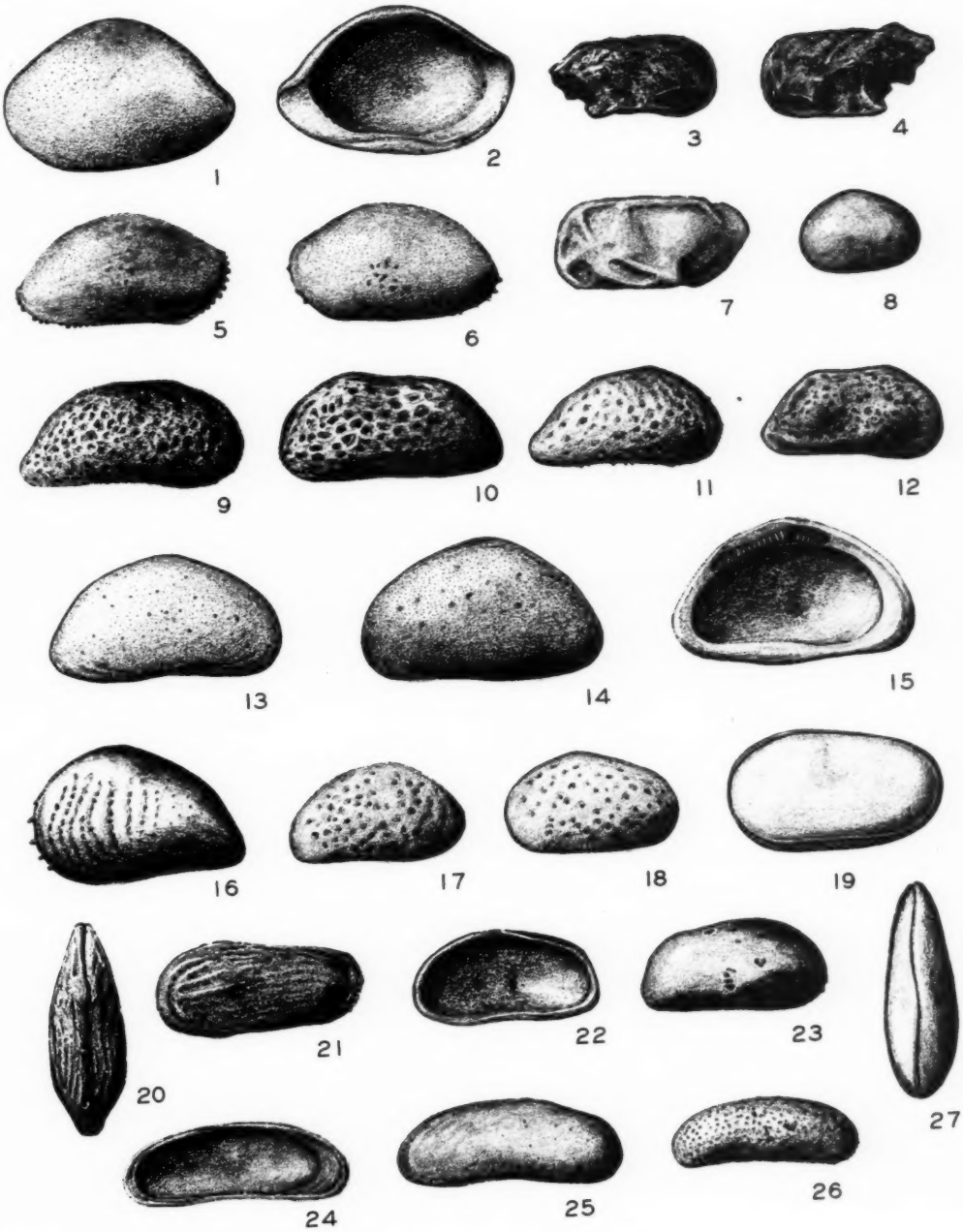
P. belhavenensis occurs in the Gosport sand at Little Stave Creek and Claiborne Bluff, Alabama, but appears much more commonly at Claiborne Bluff.

Dimensions of figured specimens.—Length (right valve), 0.53 mm.; height, 0.27 mm. Length (left valve), 0.56 mm.; height, 0.28 mm.

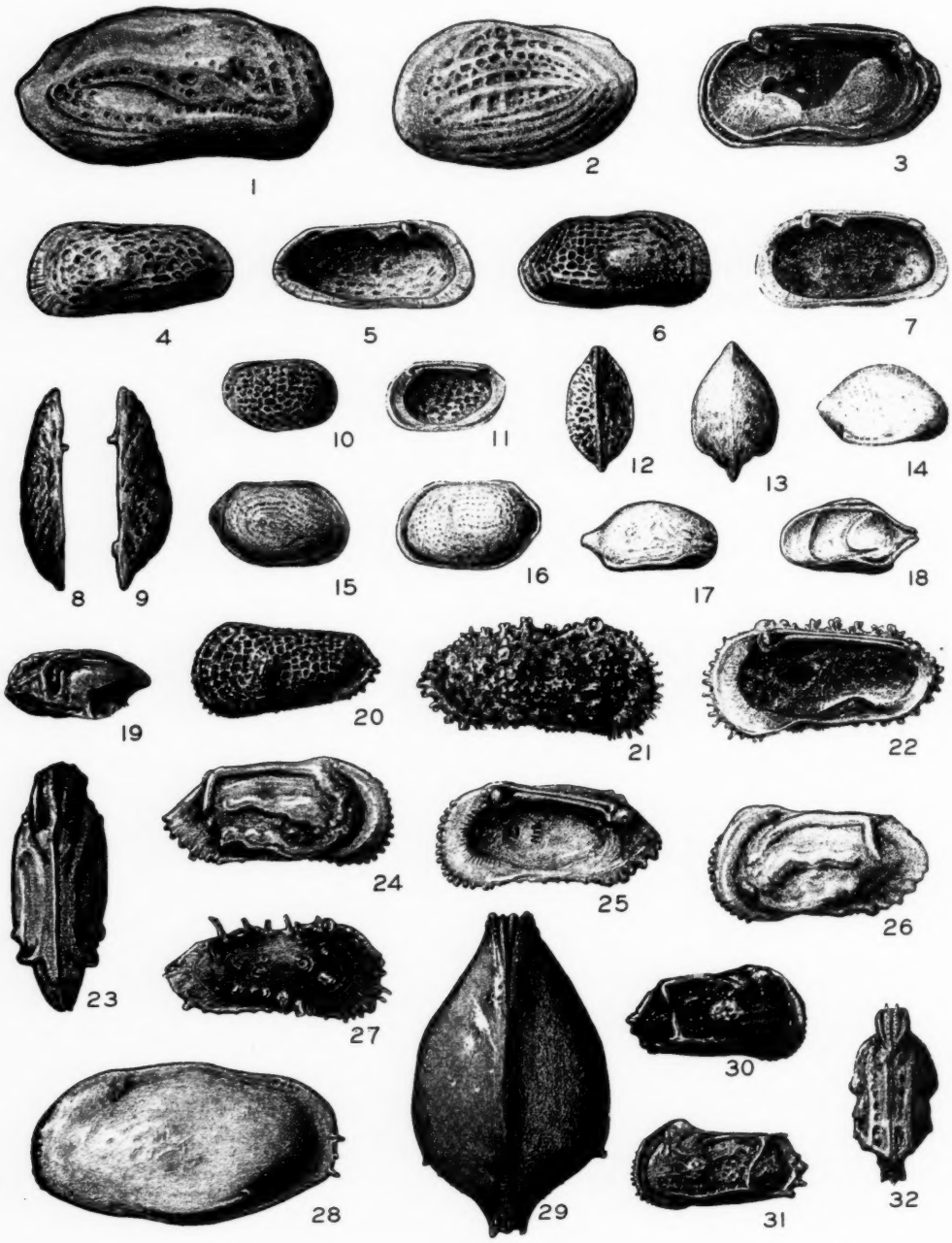
EXPLANATION OF PLATE 29

All figures ×43.

FIGS. *1, 2—Bairdoppilata* sp. Left valve. *1*, side view; *2*, interior view. (p. 175)
3, 4—Paracytheridea belhavenensis Howe and Chambers. *3*, Right valve; *4*, left valve. (p. 176)
5, 6—Bairdia gosportensis Blake, n. sp. *5*, Right valve; *6*, left valve. (p. 174)
7—Monoceratina alexanderi Howe and Chambers. Left valve. (p. 183)
8—Xestoleberis sp. Left valve. (p. 183)
9–11—Clithrocytheridea garretti (Howe and Chambers). *9*, Right valve; *10*, left valve; *11*, right valve. (p. 175)
12—Clithrocytheridea caldwellensis (Howe and Chambers). Right valve. (p. 175)
13–15—Clithrocytheridea grigsbyi (Howe and Chambers). *13*, Right valve; *14*, left valve, female, side view; *15*, interior view. (p. 175)
16—Haplocytheridea montgomeryensis (Howe and Chambers). Left valve. (p. 176)
17, 18—Haplocytheridea goochi Stephenson. *17*, Right valve; *18*, left valve. (p. 176)
19, 27—Cytherella sp., complete specimen. *19*, Left side view; *27*, dorsal view. (p. 174)
20, 21—Cythereis? longicostata Blake, n. sp. *20*, Dorsal view of complete specimen; *21*, side view of left valve. (p. 178)
22, 23—Cytherideis alta Blake, n. sp. Young molt. *22*, Right valve, interior view; *23*, right valve, side view. (p. 180)
24, 25—Cytherideis gosportensis Blake, n. sp. Left valve. *24*, interior view; *25*, side view. (p. 179)
26—Cytherideis perforata Blake, n. sp. Right valve. (p. 179)



Blake, Eocene Ostracoda



Blake, Eocene Ostracoda

Subfamily CYTHERINAE Dana, 1852
Genus BRACHYCYTHERE Alexander, 1933
BRACHYCYTHERE MARTINI Murray and Hussey
Plate 30, figures 28, 29

Brachycythere martini MURRAY and HUSSEY, 1942, Jour. Paleontology, vol. 16, p. 177, pl. 28, figs. 6, 10, text fig. 2: 4, 8–10.

This species is rather common in the Gosport sand at Little Stave Creek and Claiborne Bluff, Alabama.

B. martini Murray and Hussey and *B. watervalleyensis* (Howe and Chambers) are similar species, but may be distinguished as follows: *B. martini* has shallow surface reticulations, a relatively weak, curved ala, which ends in a small, knob-like spine well in front of the posterior end; *B. watervalleyensis* has a nearly smooth surface, a relatively strong ala which is gently arched and which ends near the posterior end in a prominent swept-back spine.

Dimensions of figured specimens.—Length (left valve), 0.99 mm.; height, 0.52 mm. Length (complete specimen), 1.03 mm.; width, 0.62 mm.

Genus CYTHERETTA Müller, 1894
CYTHERETTA ALEXANDERI Howe and Chambers
Plate 30, figures 1–3

Cytheretta alexanderi HOWE and CHAMBERS, 1935, Louisiana Dept. Cons. Geol. Bull. 5, p. 45, pl. 5, figs. 17–21; pl. 6, figs. 27, 28.
Cytheretta alexanderi, BERGQUIST, 1942, Mississippi Geol. Survey Bull. 49, p. 109, pl. 11, fig. 20.

This species shows strong sexual dimorphism. The female carapace bears a series of beveled longitudinal ribs, converging posteriorly, between which are pitted furrows. The male carapace is more elongate, with a much coarser and more variable surface sculpture. The original description of *C. alexanderi* Howe and Chambers made no mention of crenulations on the hinge line; however, a number of specimens of the Henry V. Howe collection from Jackson Eocene localities were examined and found to bear crenulate hinges. Well preserved specimens from the Gosport sand also show this structure. The reproductions of the original figures of this species were not dark enough to show properly the pits which lie within the longitudinal furrows. The species is very common in the Gosport formation at Little Stave Creek and Claiborne Bluff, Alabama.

Dimensions of figured specimens.—Length (male right valve), 1.00 mm.; height, 0.49 mm. Length (female left valve), 0.78 mm.; height, 0.47 mm. Length (male right valve interior view), 0.78 mm.; height, 0.39 mm.

EXPLANATION OF PLATE 30

All figures ×43.

FIGS. *1, 2, 3—Cytheretta alexanderi* Howe and Chambers. *1*, Male right valve; *2*, female left valve; *3*, male right valve, interior. (p. 177)
4–9—Triginglymus hyperochus Blake, n. gen., n. sp. Male left valve: *4*, side view; *5*, interior view; *8*, dorsal view. *6*, Female right valve; *7*, female right valve, interior view; *9*, dorsal view. (p. 181)
10–12—Loxoconcha stavensis Blake, n. sp. Right valve: *10*, side view; *11*, interior view. *12*, Dorsal view of complete specimen. (p. 182)
13, 14—Cytheropteron variosum Martin. *13*, Complete specimen, dorsal view; *14*, right valve, side view. (p. 182)
15, 16—Loxoconcha clarkensis Blake, n. sp. *15*, Right valve; *16*, left valve. (p. 183)
17, 18—Cytherura semireticulata Blake, n. sp. Right valve: *17*, side view; *18*, interior view. (p. 182)
19—Cytherura ultra Blake, n. sp. Left valve. (p. 182)
20–22—Trachyleberis washburni (Stephenson). *20*, Young molt, left valve. Adult right valve: *21*, side view; *22*, interior view. (p. 180)
23–26—Cythereis? gosportensis Blake, n. sp. *23*, Dorsal view, complete specimen. Right valve: *24*, side view; *25*, interior view. *26*, left valve. (p. 178)
27—Trachyleberis davidwhitei (Stadnichenko), right valve. (p. 180)
28, 29—Brachycythere martini Murray and Hussey. *28*, left valve; *29*, dorsal view, complete specimen. (p. 177)
30–32—Cythereis? collei Gooch. *30*, Right valve; *31*, left valve; *32*, dorsal view, complete specimen. (p. 178)

Genus CYTHEREIS Jones, 1849
CYTHEREIS? COLLEI Gooch
Plate 30, figures 30–32

Cythereis collei GOOCH, 1939, Jour. Paleontology, vol. 13, p. 585, pl. 67, fig. 19.

Description.—Carapace coarsely reticulate. A prominent swelling lies just in front of the center of the carapace, with three narrow ridges extending anteriorly, the uppermost trending in an arc toward the eyespot. A strong ridge begins within the antero-ventral angle and extends back parallel to the ventral margin to a point one-third the shell length from the posterior end where it rises to a point, turns abruptly and continues obliquely toward the dorsal margin; there it again turns abruptly and trends anteriorly, arching downward to an end point behind and below the eyespot.

This is a very common species in the Gosport sand at Little Stave Creek and Claiborne Bluff, Alabama.

Dimensions of figured specimens.—Length (right valve), 0.57 mm.; height, 0.31 mm. Length (left valve), 0.56 mm.; height, 0.29 mm. Length (complete specimen), 0.57 mm.; width, 0.28 mm.

CYTHEREIS? GOSPORTENSIS Blake, n. sp.
Plate 30, figures 23–26

Description.—Carapace in side view elongate, subquadrate. Dorsal margin straight, subparallel to the slightly convex ventral margin. Anterior end broadly rounded, produced beyond the dorsal and ventral margins. Posterior end angular with dorsal and ventral margins joining to form a blunt point at middle. Short, thick, blunt spines line the antero- and postero-ventral margins and several very short blunt spines appear on the ventral margin. The anterior end of carapace bears a broad, thick marginal rim, behind which is a depressed zone. A small eyespot is barely visible near the dorsal end of the anterior marginal rim. The posterior and postero-ventral areas are compressed. A narrow, prominent ridge begins below the eyespot and trends posteriorly, meeting the dorsal margin in the middle, and continues along the dorsal margin to the posterior cardinal angle where it turns ninety degrees ventrally and ends as it reaches the mid-line. A heavier and more nodular ridge lies slightly above the middle, and a fused line of heavy nodes lies just above the ventral margin. A cluster of smaller nodes appears on the antero-ventral part of the carapace within the marginal rim. Viewed from the inside the valves are moderately shallow. The marginal area is broad with the line of concrescence and the inner margin coinciding. The hinge of the right valve consists of a large, oval anterior tooth and a deep postjacent socket, followed by an elongate, straight, narrow groove, which ends at the posterior cardinal angle. A large, knob-like tooth occupies the posterior end of the hinge line. The hinge of the left valve consists of a large anterior socket followed by a large, blunt, arched tooth, which is attached to the dorsal margin. A straight, narrow, faintly notched bar continues to the posterior cardinal angle which is set with a large, ovate socket. There is a prominent muscle scar depression in front of the center of the carapace. The muscle pattern consists of a vertical row of four scars, in front of which is another large U-shaped scar.

Dimensions of figured specimens.—Length (right valve), 0.72 mm.; height, 0.33 mm. Length (left valve), 0.70 mm.; height, 0.37 mm. Width (complete specimen), 0.30 mm.

Remarks.—This species is similar to *C. reklawensis* Stephenson 1944, but differs in that the posterior end of *C. reklawensis* comes to a point well above the middle. In addition, the ventral ridge of *C. reklawensis* is much less nodular. This species is very common at Little Stave Creek and at Claiborne Bluff, Alabama.

CYTHEREIS? LONGICOSTATA Blake, n. sp.
Plate 29, figures 20, 21

Description.—Carapace elongate, highest through anterior cardinal angle, broadest posterior to middle, in side view elongate-ovate. Dorsal margin nearly straight, but slightly concave at middle; ventral margin almost straight, with dorsal margin converging slightly toward posterior end. Anterior end rather long, broadly and evenly rounded; posterior end obliquely subangular, subtruncate above and below, and bearing a few small nodes on ventral part. Postero-ventral margin compressed. A beveled marginal rim parallels the edge of the anterior and posterior ends. A narrower rim

is set behind the anterior marginal rim and terminates dorsally at the anterior cardinal angle. From the anterior curve of this second rim a number of rather sinuate longitudinal ribs extend toward the posterior end. Coarse reticulations obscure the ribs at both ends. The furrows between the ribs bear a line of coarse, shallow pits. Viewed from the inside the valves are moderately shallow. Marginal area is fairly broad and the line of concrescence and the inner margin coincide. Radial pore canals are numerous. Hinge of the left valve consists of a large, deep, anterior socket, followed by a doubly-curved, smooth blunt tooth. This tooth tapers posteriorly to a long narrow bar which ends at the posterior cardinal angle and is separated from the dorsal margin by an incised line. The posterior cardinal angle is occupied by an ovate socket over which the dorsal margin curves.

Dimensions of figured specimens.—Length (left valve), 0.67 mm.; height, 0.40 mm. Length (complete specimen), 0.68 mm.; width, 0.24 mm.

Remarks.—This species is moderately scarce in the Gosport sand at Little Stave Creek and Claiborne Bluff, Alabama.

Genus CYTHERIDEIS Jones, 1856

CYTHERIDEIS GOSPORTENSIS Blake, n. sp.
Plate 29, figures 24, 25

Description.—Carapace elongate, highest and broadest posterior to middle, elongate-ovate in side view. Left valve overlaps right along anterior dorsal margin, and slightly along postero-ventral margin. Dorsal margin broadly arched; ventral margin gently concave. Anterior end somewhat narrowly rounded and faintly denticulate. Posterior end bluntly and rather obliquely rounded, meeting dorsal margin at a slight angle. Shell wall smooth. Normal pore canals moderately few and widely spaced, marking the surface with shallow pits. Anterior one-third of carapace may bear a series of low undulations parallel to margins, apparently caused by alignment of normal pore canals. Viewed from the inside, valves are moderately shallow. A broad marginal area extends around the anterior end, with the line of concrescence lying slightly within the inner margin. The postero-ventral edge of right valve bears a depressed seat which receives the postero-ventral edge of left valve. Muscle scar pattern obscure, but appears to be a vertical row of four behind a larger U-shaped spot, with additional spots scattered above and below. Hinge line narrow, composed of two nearly straight segments which meet at a broad angle posterior to the middle. Hinge of right valve bears a narrow groove; hinge of left valve carries a narrow bar which tapers into the marginal rim of posterior end. An incised line separates the hinge bar from the dorsal margin.

Dimensions of figured specimen.—Length, 0.72 mm.; height, 0.23 mm.

Remarks.—This species resembles *Cytherideis mcguirti* (Howe and Garrett) from the Sabine (Wilcox) Eocene of Louisiana, but differs in shape by having a broader anterior end with coarser denticulations.

CYTHERIDEIS PERFORATA Blake, n. sp.
Plate 29, figure 26

Description.—Carapace elongate, highest just anterior to middle; in side view elongate-ovate. Left valve overlaps right along antero-dorsal and posterior margins. Dorsal margin broadly arched; ventral margin gently concave. Anterior end rounded, slightly denticulate; posterior end bluntly rounded, more broadly rounded in left valve. Surface covered with moderately coarse, shallow, ovate pits, aligned approximately parallel to edge near antero-ventral margin. Viewed from inside, the valves are fairly shallow, with a broad marginal area around the anterior end and a narrow one around the ventral and posterior margins. Line of concrescence lies within the inner margin at the end, with a small vestibule visible below the inner part of the marginal area. Dorsal contact margin narrow, with an elongate groove in hinge of right valve. Hinge of left valve has a long, narrow bar which is separated from the dorsal margin by a finely incised line.

Dimensions of figured specimen.—Length, 0.60 mm.; height, 0.20 mm.

Remarks.—This species resembles *Cytherideis mayeri* (Howe and Garrett) from the Sabine (Wilcox) Eocene of Louisiana, but distinctly differs from that species by having no "trench" or sulcus carved obliquely from the dorsal margin. In addition, *C. perforata* does not appear to be as strongly pitted.

CYTHERIDEIS ALTA Blake, n. sp.
Plate 29, figures 22, 23

Description.—Carapace in side view elongate-ovate; greatest length just above ventral margin. Dorsal margin broadly arched; ventral margin gently concave. Anterior end rather broad, obliquely rounded, and faintly denticulate. Posterior margin meets dorsal margin in a smooth curve and tapers toward ventral margin which it meets at a well-rounded angle. Shell wall smooth except for a few small, widely-spaced shallow pits. Viewed from inside, valves are moderately shallow. Marginal area is fairly broad around the anterior end and the line of concrescence lies near the inner margin. The muscle scars consist of a vertical row of four spots with a large V-shaped scar in front of the top spot of the row. Above this group are several muscle scars near the dorsal margin, the center pair of which form a crescentic spot with a small ovate scar partly enclosed below it. A small, elongate-ovate scar lies between the anterior dorsal scar and the central group. Two additional scars are set obliquely below the central group. The hinge of the right valve bears an elongate narrow groove which receives the narrow hinge bar of the left valve.

Dimensions of figured specimen.—Length (young molt), 0.60 mm.; height, 0.29 mm.

Remarks.—This species occurs in the Gosport sand at Little Stave Creek and Claiborne Bluff, Alabama, but is rather scarce at both localities. It is easily distinguished from *C. gosportensis* Blake n. sp. by its greater height. The adult valves have the same shape as the young molts, but are larger and thicker, with a broader marginal area around the anterior end. A young molt was chosen for figuring because the muscle scars are clearly visible, which is not the case in the adult valves.

Genus TRACHYLEBERIS Brady, 1898

Genotype.—*Cythere scabrocuneata* Brady, 1880, p. 103, pl. 17, figs. 5a–5c.

The genus *Trachyleberis*, described by Brady, was based on a species from New Zealand. It was reestablished by Sylvester-Bradley, 1948, in this journal, vol. 22, p. 794, pl. 122, figs. 13–18. The following two species belong to this group.

TRACHYLEBERIS DAVIDWHITEI (Stadnichenko)
Plate 30, figure 27

Cythereis davidwhitei STADNICHENKO, 1927, Jour. Paleontology, vol. 1, p. 240, pl. 39, fig. 24.
Cythereis gibsonensis HOWE and CHAMBERS, 1935, Louisiana Dept. Cons. Geol. Bull. 5, p. 29, pl. 1, fig. 22; pl. 6, figs. 21, 22
Cythereis quinquespinosa SUTTON and WILLIAMS, 1939, Jour. Paleontology, vol. 13, p. 566, pl. 63, figs. 10, 11.
Cythereis davidwhitei, STEPHENSON, 1946, *idem*, vol. 20, p. 336, pl. 44, fig. 5; pl. 45, fig. 12.

Description.—Carapace in side view elongate-subquadrate. About four long, blunt, widely-spaced, gently arched spines project in a line just below the dorsal margin. Another spine extends from the posterior cardinal angle of the left valve. Several prominent spines lie along the central part of the carapace, the anterior one of which is offset ventrally. Another line of spines begins above the postero-ventral margin, arching downward anteriorly to the ventral margin. One or more additional spines are situated below the posterior cardinal angle. With the exception of a few small, scattered nodes, the remainder of the carapace is smooth and polished.

Dimensions of figured specimen.—Length, 0.70 mm.; height, 0.33 mm.

Remarks.—A close comparison of the Gosport specimens with the types of *Cythereis gibsonensis* Howe and Chambers, and the hypotypes of *C. davidwhitei* Stadnichenko of Stephenson, revealed that no constant difference exists. All apparently fit the original description of *C. davidwhitei* Stadnichenko.

This species occurs at Little Stave Creek and at Claiborne Bluff, Alabama, in the Gosport formation, but in no abundance. The known range, therefore, extends from the lower Claiborne to the top of the Jackson Eocene.

TRACHYLEBERIS WASHBURNI (Stephenson)
Plate 30, figures 20–22

Cythereis washburni STEPHENSON, 1944, Jour. Paleontology, vol. 18, p. 452, pl. 76, fig. 8.

Surface of carapace is covered with spines, some heavy and branching into star-shaped ends, others shorter and pointed. They rise

from ridges which produce coarse, but obscured, reticulations. The original description of this species was based on female(?) specimens because no mention was made of an elongate form. I have observed both long and short forms in the Gosport, and consider them to be males and females of the same species. This is a fairly common species in the Gosport at Little Stave Creek and at Claiborne Bluff, Alabama, but may not be easily recognized because foreign matter, wedged between the spines, masks the surface and more than ordinary washing is necessary to remove it.

Dimensions of figured specimens.—Length, 0.78 mm.; height, 0.37 mm. Young molt: length, 0.60 mm.; height, 0.30 mm.

Genus TRIGINGLYMUS Blake, n. gen.

Genotype. — Triginglymus hyperochus Blake, n. sp.

This genus belongs to that group of ostracods known formerly under the genus *Cythereis* Jones, but differing from that and all subsequent genera in the possession of a triangular, "anti-slip" tooth behind the anterior cardinal angle and just anterior to and below the middle of the dorsal margin. The outline of the carapace is nearest to that of *Leguminocythereis*, but that genus has no such tooth.

TRIGINGLYMUS HYPEROCHUS Blake, n. sp.
Plate 30, figures 4–9

Description.—Carapace in side view elongate-subquadrate; viewed from above, broadest posterior to middle. Dorsal margin nearly straight; ventral margin somewhat sinuous, converging slightly toward posterior. Anterior end broadly and obliquely rounded, faintly denticulate below middle. A low, moderately broad marginal rim parallels the anterior end, and continues as a narrow rim along the ventral and posterior margins. A low, roughly circular muscle scar swelling lies near the center of the carapace, behind which the valve is inflated, especially in the females, the inflation being greatest just above the ventral margin. The surface is ornamented with coarse, shallow reticulations which roughly parallel the margins. Those aligned over the posteroventral inflation are elongate-ovate in outline; the remainder are more nearly equidimensional. There are several low ridges on the flattened venter, trending subparallel to the line of contact of the valves, and becoming obscured by the pitting around the ends. Viewed from the inside the valves are moderately deep. The external pitting is clearly visible through the shell wall. Marginal area fairly broad, with line of concrescence and inner margin not coinciding. Radial pore canals numerous around anterior end, less so around posterior and ventral margins. The muscle scar pattern consists of a vertical row of four elongate-ovate spots, with two oblique scars in front of the upper two spots of the row. An ocular sinus lies in front of and below the anterior cardinal angle. The hinge of the right valve consists of a high, almost cylindrical anterior tooth followed by a deep, triangular socket which tapers into a narrow, smooth or faintly notched groove. The groove continues just below the dorsal margin, turning downward slightly near the posterior cardinal angle, which is occupied by an elongate, oval, blunt tooth. A large, subtriangular lobe projects ventrally and somewhat laterally from the zone below the dorsal groove and just behind the anterior tooth and socket. The hinge of the left valve consists of a deep, almost circular anterior socket, followed by a blunt tooth which arches downward anteriorly, and is drawn out posteriorly into a narrow bar. The bar bends slightly downward at the posterior cardinal angle which is occupied by an elongate-ovate socket. A subtriangular lobe is produced ventrally and somewhat laterally from the zone below the hinge line and just behind the anterior tooth.

Dimensions of figured specimens.—Male left valve: length, 0.65 mm.; height, 0.30 mm.; depth 0.13 mm. Female right valve: length, 0.60 mm.; height, 0.38 mm. Right valve, dorsal view: length, 0.62 mm.; depth, 0.17 mm.

Remarks.—This species occurs rather commonly in the Gosport sand at Little Stave Creek and at Claiborne Bluff, Alabama. It is recognized by the triangular hinge projection.

Subfamily CYTHERURINAE Müller, 1894
Genus CYTHEROPTERON Sars, 1865
CYTHEROPTERON VARIOSUM Martin
Plate 30, figures 13, 14

Cytheropteron variosum MARTIN, 1939, Jour. Paleontology, vol. 13, p. 178, pl. 22, figs. 7–9.

Description.—Carapace small; dorsal margin strongly arched; ventral margin gently convex. A prominent, but not greatly produced, ala roughly parallels the ventral margin, barely concealing it. Surface ornamentation varies: some specimens are almost entirely smooth; others have, in varying degree, rows of vertically aligned, elongate, shallow pits extending from the ala almost to the dorsal margin. The anterior one-third of all specimens is smooth. This is a common Gosport species at Little Stave Creek and Claiborne Bluff, Alabama.

Dimensions of figured specimens.—Length (right valve), 0.43 mm.; height, 0.36 mm. Length (complete specimen), 0.44 mm.; width, 0.28 mm.

Genus CYTHERURA Sars, 1865
CYTHERURA SEMIRETICULATA Blake, n. sp.
Plate 30, figures 17, 18

Description.—Carapace small, in side view subovate. Dorsal margin strongly arched, tapering posteriorly; ventral margin nearly straight. Anterior end regularly rounded; posterior end drawn out into a bluntly pointed caudal process just below middle. A prominent alate ridge begins within the antero-ventral angle and continues posteriorly in a broad arch to the postero-ventral angle. Ventral margin is barely obscured by the ala. Several irregular longitudinal ridges lie on the upper slope of the ala. Carapace is marked with broad, shallow reticulations above these ridges. Viewed from the inside the valves are deep. Marginal area very broad, depressed, with posterior inner margin extending as a wide lobe to center of carapace. Line of concrescence and inner margin coincide. Hinge of right valve bears a straight groove below the dorsal margin, with dorsal edge of left valve apparently fitting into it.

Dimensions of figured specimen.—Length, 0.43 mm.; height, 0.21 mm.

Remarks.—This species is rather scarce in the Gosport sand at Little Stave Creek, Alabama. It does not appear in Murray's Claiborne Bluff sample which I have examined.

CYTHERURA ULTRA Blake, n. sp.
Plate 30, figure 19

Description.—Carapace in side view elongate-subquadrate. Dorsal and ventral margins almost straight and parallel. Anterior end regularly rounded, bearing a fragile, roughly scalloped rim. Posterior end tapered into a bluntly pointed caudal process. A prominent, arched ala overhangs the ventral margin. It is crested with two very sharp, fragile ridges, the lower of which merges with the anterior rim. The upper ridge begins beside the first near the antero-ventral angle and ends at the posterior ventral angle. A coarsely pitted groove separates the sharp crest of the ala from a beveled rib, which extends subparallel to the ala to a point past the middle of the shell. A similar rib is present on the dorsal margin. Another rib extends in an arc, convex forward, from near the middle of the dorsal rib to the supra-ala rib. A branch extends anteriorly downward from the middle of the arc. A vertical sinus lies behind the arc, and is followed by a sigmoid rib which joins the supra-ala rib. A curved rib lies above the postero-ventral angle. The area behind the center of the carapace is smooth and gently inflated. Viewed from the inside the valves are deep. Marginal area depressed and very broad, with posterior inner margin extending as a wide lobe to the center of carapace. The inner margin at the anterior end reaches a line through the anterior cardinal angle. The line of concrescence and the inner margin coincide. The hinge of the right valve carries a narrow groove below the dorsal margin which probably receives the dorsal margin of the left valve.

Dimensions of figured specimens.—Length, 0.45 mm.; height, 0.21 mm.

Remarks.—This species is rare at Little Stave Creek, Alabama, in the Gosport section. It was not observed in the Claiborne Bluff sample of Dr. Murray.

Subfamily LOXOCONCHINAE Sars, 1926
Genus LOXOCONCHA Sars, 1865
LOXOCONCHA STAVENSIS Blake, n. sp.
Plate 30, figures 10–12

Description.—Carapace small, in side

view subrhomboidal. Dorsal and ventral margins nearly straight or slightly convex. Anterior end broadly and evenly rounded; posterior end bluntly angular, obliquely truncate above and evenly rounded below. A slight keel formed by the ventral margin produces a faint offset on the otherwise smooth sweep of the posterior and ventral margins. Margins smooth; remainder of carapace covered with deep, subangular to rounded pits arranged in a reticulate pattern throughout. Alignment of pits seems to be accidental and inconsistent, but total lack of alignment is more common. A low rib lies above the postero-ventral margin. Viewed from the inside the valves are moderately deep. Hinge of right valve consists of a weak U-shaped anterior tooth which opens dorsally, followed by an elongate, narrow, finely-crenulated groove, and ending at the posterior cardinal angle with a weak, claw-like tooth which opens antero-ventrally. Hinge of left valve equipped with claw-like terminal teeth which apparently articulate with those of the right valve, and which are connected by a long, straight, finely-crenulate bar. Marginal area fairly broad with line of concrescence and inner margin not coinciding at the ends.

Dimensions of figured specimens.—Length (right valve), 0.37 mm.; height, 0.22 mm. Length (complete specimen), 0.40 mm.; width, 0.21 mm.

Remarks.—This species resembles *L. creolensis* Howe and Chambers, described from the Jackson Eocene, but is easily distinguished from that species by having no definite alignment of pits, those of *L. creolensis* being arranged in longitudinal rows.

LOXOCONCHA CLARKENSIS Blake, n. sp.
Plate 30, figures 15, 16

Description.—Carapace in side view subrhomboidal, highest and broadest slightly posterior to middle. Dorsal and ventral margins nearly straight and parallel. Anterior end broadly and obliquely rounded; posterior end bluntly pointed above middle, truncate above, broadly and evenly rounded below. Margins smooth; remainder of carapace covered with moderately fine pits arranged in rows roughly parallel to margins. The size of the pits varies slightly on different specimens. Viewed from the inside the valves are moderately deep, flanked by a fairly broad marginal area. Line of concrescence and inner margin do not coincide at the ends. Radial pore canals few and widely spaced. Hinge of the right valve consists of claw-like terminal teeth connected by a long, straight, narrow, crenulate groove. Hinge of the left valve equipped with claw-like terminal teeth which interlock with those of the right valve, and which are separated by a straight, narrow bar which fits into the groove of the right valve.

Dimensions of figured specimens.—Length (right valve), 0.45 mm.; height, 0.27 mm. Length (left valve), 0.46 mm.; height, 0.28 mm.

Remarks.—This species closely resembles *L. vernonensis* Howe and Chambers, described from the Jackson Eocene of Louisiana, but differs in having larger and fewer pits, and an unconcealed ventral margin. *L. clarkensis* has a slight keel on the posterior venter, whereas *L. vernonensis* is rather flattened in that region.

Subfamily BYTHOCYTHERINAE Sars, 1926
Genus MONOCERATINA Roth, 1928
MONOCERATINA ALEXANDERI Howe and Chambers
Plate 29, figure 7

Monoceratina alexanderi HOWE and CHAMBERS, 1935, Louisiana Dept. Cons. Geol. Geol. Bull. 5, p. 21, pl. 3, fig. 19; pl. 4, fig. 21.

This species, originally reported from Jackson Eocene localities, is rather scarce at Little Stave Creek in the Gosport section.

Dimensions of figured specimen.—Length, 0.62 mm.; height, 0.29 mm.

Subfamily XESTOLEBERINAE Sars, 1928
Genus XESTOLEBERIS Sars, 1865
XESTOLEBERIS sp.
Plate 29, figure 8

A small species of *Xestoleberis* occurs sparingly in the Gosport formation at Little Stave Creek; it is considerably smaller than *X. sarsi* Howe and Chambers from the Jackson Eocene of Louisiana. Because only a few separate valves were found, it seems inadvisable to present a detailed description.

Dimensions of figured specimen.—Length, 0.38 mm.; height, 0.27 mm.

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AMMONOIDS OF THE PENNSYLVANIAN FINIS SHALE OF TEXAS

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ABSTRACT—The largest single ammonoid fauna known from the Upper Pennsylvanian is that of the Finis shale member of the Graham formation of north-central Texas. It consists of 15 species, each of which is illustrated and discussed. These belong in the following 11 genera: *Uddenites*, *Imitoceras*, *Goniolobоceras*, *Neodimorphoceras*, *Eoasianites*, *Schistoceras*, *Eothalassoceras*, *Agathiceras*, *Peritrochia*, *Shumardites*, and *Vidrioceras*. One new species is established—it is referable to *Vidrioceras*.

WITH the possible exception of the southern Ural region and one or two localities in Kansas, late Upper Carboniferous ammonoids seem to be abundant and varied only in Texas. The strata which have yielded the best material are portions of the Graham formation of the north-central part of that state. They carry two closely related cephalopod faunas which occur about 300 or 400 feet apart stratigraphically. The older of these is in the basal portion of the formation, the Finis shale; whereas the younger is reported from the beds between the Bunger limestone and the Avis conglomerate, just above the middle of the Graham. The latter is stated by Plummer and Scott (1937, p. 18) to be the "best-known ammonite zone in the north-central Texas section." However, the collections that have recently become available from the Finis shale, a relatively small and definite stratigraphic unit, contain more individuals and approximately the same number of genera and species, and the specimens are about equally well preserved.

Because of these facts, the Finis shale material offers a unique opportunity to acquire a reasonably comprehensive understanding of a large and varied Upper Pennsylvanian ammonoid fauna, with which others can be compared and contrasted to advantage. We therefore have assembled as many specimens as possible from this shale, and have studied them in detail. At different times we visited many of the outcrops and secured a quantity of material. Other collections were obtained from Messrs. James P. Conlin of Forth Worth, Ralph H. King of Wichita Falls, John Britts Owen of Clinton (Missouri), Robert C. Spivey of the Shell Oil Company, Merrill A. Stainbrook of Brandon (Iowa), Robert J. Stark of Grapevine (Texas), and Mrs. H. J. Renfro of Fort Worth—King's type and figured specimens are to be deposited in the U. S. National Museum. Messrs. M. G. Cheney of Coleman (Texas), Wallace Lee of the U. S. Geological Survey, and Robert C. Spivey of the Shell Oil Company advised us in regard to the stratigraphy involved. Acknowledgement is also due to the late Drs. F. B. Plummer and Gayle Scott, whose volume on "Upper Paleozoic ammonites in Texas" has been of very great assistance to us. The photographs which accompany our report were retouched by Mr. Howard Webster of Iowa City, and he also drew the text figures. The Graduate College of the State University of Iowa and particularly Mr. F. O. Thompson of Des Moines made the completion of the report financially possible.

THE FINIS SHALE

In their well-known study, "Stratigraphy of the Pennsylvanian formations of north-central Texas," Plummer and Moore (1922, p. 127) named the beds which they regarded as the "oldest portion of the [basal Cisco] Graham formation" after a small town, Finis, in the Brazos River Valley, close to the southwest corner of Jack County. They state that these "strata consist of sandy shale with interbedded sandstone 50 to 100 feet or more in thickness, which rest on the Home Creek limestone at the top of the Canyon group. This member . . . may be identified southward from its type locality by its position between the massive Canyon

limestones and the Jacksboro limestone of the Graham formation."

Subsequent authors shifted the boundary between the Canyon and the Cisco groups and adjusted the details of the stratigraphic terminology to coincide with their particular views; and for a time (see Sellards, 1933, p. 114) the Jacksboro limestone and the Finis shale were considered to be "part of the Home Creek limestone." However, in their report on the "Geology of Palo Pinto County, Texas," which lies immediately south of Jack County, Plummer and Hornberger (1936, p. 62) defined the Finis shale as the 50-foot basal portion of the Graham formation and therefore of the Cisco group. This interpretation was accepted by the United States Geological Survey (Wilmarth, 1938, p. 731), and we also are essentially following it. However, Wallace Lee has recently written us that in Young County (just west of Jack County) the 1-foot-thick Salem School limestone lies only about 5 feet above the Home Creek though it is separated from it "by a considerable hiatus which is obscure except where revealed by the Kisinger channel." It seems to us that the base of the Cisco should be drawn at that hiatus, and that therefore the Finis does not include the basal few feet of the Cisco. That is, according to Lee, the "name Finis shale was given to the sequence overlying the original Home Creek and is therefore the sequence above the Salem School limestone."

The Finis shale outcrops in a rather narrow belt extending northeast and southwest from its type locality. To the southwest it thins and does not seem to have been recognized for more than about 13 miles, at which point, however, it is 52 feet thick according to Plummer and Hornberger (1936, p. 63). Its best development is northeast of Finis in the central and northeastern portions of Jack County, where the member is quite variable in thickness and composition. In the vicinity of Jacksboro, near the center of the county, according to Spivey (1936, p. 31) it "consists of about 200 feet of light yellow, sandy shale with two 6-foot sandstone layers near the middle. To the northeast the lower sandstone increases to a thickness of about 15 feet," and three thin limestone lenses, called the Cundiff limestone, appear within the shale. "Each layer of limestone is from one to three feet thick and is separated from the others by 60 to 70 feet of shale." Scott and Armstrong (1932, p. 38) stated that the exposures are relatively poor immediately east of Jack County, and not far from there these Pennsylvanian strata disappear altogether under Lower Cretaceous sandstones.

THE FAUNA OF THE FINIS SHALE

Several authors have reported that the Finis shale contains exceptionally well preserved marine invertebrates in abundance and variety. For example, Plummer and Hornberger (1936, p. 64) stated: "The fossils from the lower member of the Graham formation are about the best preserved and most interesting assemblages in the Pennsylvanian section. They are characterized by the well-known discoidal ammonite, *Uddenites*, and its associated cephalopods, *Marathonites* [=*Peritrochia*], *Agathiceras*, *Schistoceras*, *Goniolobоceras*, and *Gastrioceras* [*Eoasianites*], thus constituting the richest ammonoid zone in the entire section." Furthermore the specimens are more resistant to weathering than the enclosing matrix, a soft sandy shale; and at many of the outcrops free fossils can therefore be picked up in quantity.

Our collections and the published list make it clear that the fauna of the Finis shale consists of a few plants, fusulinids, sponges, conularids, and crinoids, and a variety of corals, bryozoans, and particularly brachiopods, pelecypods, gastropods, and cephalopods. Nautiloids are more abundant than ammonoids, with which they occur in direct association—the chief nautiloid genera are *Pseudorthoceras*, *Mooreoceras*, *Bactrites?*, *Brachycycloceras*, *Poterioceras*, *Liroceras*, *Domatoceras*, *Metacoceras*, and *Tainoceras*. However, we propose to consider in detail only the ammonoids. Some of these have been listed and discussed more or less incidentally by authors who were primarily interested in stratigraphy, and in their well-known volume on "Upper Paleozoic ammonites in Texas" Plummer and Scott included illustrations and descriptions of essentially all the species. However, none of the previous authors seems to have had available anything like

the wealth of material that we have assembled, and therefore the scope of their studies was relatively limited.

Altogether, the following species of ammonoids are now known from the Finis shale:

Uddenites oweni Miller and Furnish
Imitoceras grahamense (Plummer and Scott)
Goniolobоceras goniolobum (Meek)
Neodimorphoceras texanum (Smith)
Eoasianites anguloumbilicatus (Plummer and Scott)
E. millsi (Miller and Cline)?
E. modestus (Böse)
Schistoceras hildrethi (Morton)
S. missouriense (Miller and Faber)
Eothalassoceras caddoense (Plummer and Scott)
Agathiceras ciscoense Smith
Peritrochia ganti (Smith)
Shumardites cuyleri Plummer and Scott
Vidrioceras uddeni Böse
V. conlini Miller and Downs, n. sp.

This list seems to differ considerably from that of Plummer and Scott (1937, pp. 17–18). However, they referred to *U. schucherti* the form we are identifying as *Uddenites oweni*, our *Imitoceras grahamense* is their *Neoaganides grahamensis*, our *Goniolobоceras goniolobum* is their *G. welleri* and their *Wiedeyoceras pinque*, our *Eoasianites modestus* is their *Glaphyrites kansasensis*, our *Schistoceras hildrethi* is their *Paraschistoceras hildrethi*, our *Schistoceras missouriense* is their *S. missouriense* and their *S. diversicostatum*, our *Eothalassoceras caddoense* is their *Prothalassoceras kingorum*, our *Agathiceras ciscoense* is their *A. ciscoense* and probably also their *A. frechi*, and our *Peritrochia ganti* is their *Marathonites ganti* and their *M. sulcatum*. These authors (Plummer and Scott, 1937, p. 18, pl. 38, figs. 11, 12) stated that their species, *Trochilioceras tenuosum*, occurs in this fauna, but in their description of that species, they listed it only from the Home Creek limestone, which underlies the Finis shale and is uppermost Canyon, rather than basal Cisco, in age. The specimen they figured from 3½ miles southeast of Jacksboro probably came from the Finis shale, but we suspect that this is an immature representative of one of the species listed above.

COMPARISONS WITH RELATED AMMONOID FAUNAS

Spivey (1936, p. 28) stated that "most of the fossils that occur in these shales occur also in the shales between the layers of the [immediately overlying] Jacksboro limestone," and he has recently written us that we may have trouble determining whether certain specimens came from a shale between beds of Jacksboro limestone or from below the Jacksboro. Nevertheless, insofar as we have been able to ascertain, only one fauna is involved.

Probably this fauna can be recognized in the valley of the Colorado River, about one hundred miles to the south, where Upper Pennsylvanian strata are well developed and exposures are numerous. Lee (1938, pl. 10) reported the presence of an ammonoid zone there in a shale which lies only a few feet above the Home Creek limestone (as does the Finis in the valley of the Brazos). However, he has recently written us that he thinks "the Finis shale or its replacements are not represented in the Colorado River area by reason of wedging out or beveling." Furthermore, he (1938, pl. 10) stated that in the valley of the Brazos there is an ammonoid zone a few feet above the Bunger limestone, and his plate (a correlation chart) seems to suggest that this zone probably correlates directly with the ammonoid zone slightly above the Home Creek limestone in the Colorado River valley. Plummer and Scott (1937, p. 18) regarded the ammonoids which come from the beds between the Bunger limestone and the Avis conglomerate as constituting a single fauna, and if that is correct, the ammonoids from just above the Bunger are presumably very similar to those which occur in the slightly younger Wayland shale, which lies just below the Avis. The Wayland shale, according to Lee, is recognizable in the valleys of both the Brazos and the Colorado. Its abundant ammonoid fauna is very much like that of the Finis, and most of the species found in one occur also in the other. However, the only species of *Shumardites* known from the Wayland, *S. simondsi* Smith, is distinctly more advanced than the congeneric form of the Finis, *S. cuyleri* Plummer and Scott. Also, *Schistoceras hildrethi* (Morton) is much more abundant

in the Wayland than in the Finis, and the genus *Daraelites* is known to be represented in the Wayland but not in the Finis—it is, however, rare in the former. These differences should enable one to determine whether the ammonoids, which according to Lee (1938, pp. 25, 167–168) occur a few feet above the Bunger, are part of the fauna of the Finis or of the Wayland, or are intermediate, as are the beds which carry them. Stratigraphically they are closer to the Wayland than the Finis.

The first extensive ammonoid fauna known from below the Finis is that of the Graford formation some 850 feet lower in the section. It carries a few species in common with the one we are studying: *Goniloboceras goniolobum* (Meek), *Eoasianites anguloumbilicatus* (Plummer and Scott), *Schistoceras hildrethi* (Morton), and *S. missouriense* (Miller and Faber). Furthermore, both contain representatives of the genus *Peritrochia*, and the Graford carries *Parashumardites* which is close to *Shumardites*. However, as might be expected because of its stratigraphic position, the fauna of the Graford is distinctly more primitive than is that of the Finis, for it is characterized by *Prouddenites* rather than *Uddenites*, and it does not contain *Neodimorphoceras* or *Vidrioceras* or any genus (except *Parashumardites*) which is not represented also in the Finis.

Closely related assemblages of ammonoids are also known from the upper part of the Gaptank formation of west Texas at two localities: (1) the saddle on the butte just west of Wolf Camp in the Glass Mountains, and (2) about five miles northeast of Wolf Camp. The containing beds at these localities may not be exactly contemporaneous, but they are not greatly different in age. The former, which is particularly famous, has yielded the following species of ammonoids:

Uddenites schucherti Böse
Daraelites texanus Böse
Neodimorphoceras texanum (Smith)
Eoasianites deciensis (Plummer and Scott)
E. modestus (Böse)
E. ruzencevi Miller and Furnish
Plummerites incertus (Böse)
Schistoceras hildrethi (Morton)
S. missouriense (Miller and Faber)
Agathiceras frechi Böse
Peritrocha "j. p. smithi" (Böse)
Shumardites simondsi Smith
Vidrioceras uddeni Böse

Both the Finis and the Wayland shales of north-central Texas contain representatives or close counterparts of almost all of these species. The occurrence of *Daraelites texanus* and particularly *Shumardites simondsi* in this Gaptank assemblage seems to indicate that the relationship is closer to the fauna of the Wayland than to that of the Finis. However, it should be emphasized that only one specimen of the latter species is known from the Gaptank; and it has never been illustrated, nor have we studied it.

From the second locality in the upper part of the Gaptank, that is, from about five miles northeast of Wolf Camp, the following species of ammonoids are now known:

Neopronorites boesei (Smith)
Uddenites oweni Miller and Furnish
Daraelites texanus Böse
Eoasianites modestus (Böse)
Neodimorphoceras texanum (Smith)
Schistoceras hildrethi (Morton)
S. missouriense (Miller and Faber)
Eothalassoceras keytei (Smith)
Peritrochia "j. p. smithi" (Böse)

This assemblage also is very similar to those found in the Finis and the Wayland shales, and especially the occurrence of *Uddenites oweni* in it suggests a relationship to the Finis. However, in the large collections that we are studying from that shale, there are no counterparts of *Neopronorites boesei* and *Daraelites texanum*, and therefore we are inclined to doubt that the two faunas are exactly equivalent. In order to prevent any possibility of ambiguity, it should be stated that the fauna known from the Gaptank southeast of Lenox, Texas, is distinctly older than that of the Finis as it is characterized by the presence of the genus *Prouddenites* as well as *Uddenites*.

In south-central New Mexico, an Upper Pennsylvanian ammonoid fauna is known from near Tularosa. There are representatives of *Goniloboceras*, *Eoasianites*, and *Shumardites* in it. Although these genera are also represented in the Finis shale, the

general aspect of the two faunas is not very similar, and there is no good reason to believe that they are closely related. Furthermore, the single specimen of *Shumardites* found at Tularosa, though not very well preserved, seems to be more advanced than *S. cuyleri* and *S. simondsi* and, therefore, it suggests that the containing beds are younger than the Finis and the Wayland shales.

No faunas are known from the northern Mid-Continent region that compare favorably with that of the Finis. In Oklahoma, perhaps the most similar is that of the Nellie Bly, which is distinctly older. Although these two faunas carry in common such long-ranging species as *Goniolobocerasgoniolobum* and *Schistoceras missouriense*, and the genera *Eoasianites* and *Peritrochia* are represented in both, they are otherwise not very similar. The Nellie Bly is characterized by *Prouddenites* rather than *Uddenites* and *Parashumardites* rather than *Shumardites*. In the Finis there are no counterparts of *Daraelites* and *Eupleuroceras*, and in the Nellie Bly there are none of *Imitoceras, Neodimorphoceras, Eothalassoceras, Agathiceras, and Vidrioceras.*

Somewhat more to the north, in east-central Kansas at Emporia and northeast of Piedmont, abundant small limonitic internal molds of ammonoids (and a very few nautiloids) weather out of the Upper Pennsylvanian Dry shale, just above the Dover limestone. Most of these seem to be referable to two species, *Imitoceras grahamense* and *Goniolobocerasgoniolobum*, and the representatives of the latter are all more or less immature. According to Smith (1929, p. 67), *Gastrioceras* [=? *Eoasianites*], *Neodimorphoceras*, and *Marathonites* [=*Peritrochia*] also occur at Emporia, but like Elias (1936, p. 695) we have not found any representatives of the last two of these genera among the hundreds of specimens we have examined. The fact that all three of the genera and the two established species of ammonoids that are definitely known to occur in the Dry shale are also present in the Finis might be taken to indicate that these faunas are closely related, but this conclusion is not warranted. The Dry shale contains a "dwarfed fauna," and all of the specimens we have seen from it are representatives of long-ranging types. None of the Finis forms that we regard as diagnostic are present in the Dry, and in our opinion the similarity between the two faunas is far more apparent than real. The differences are presumably due to age, ecology, etc., and it is generally believed that the Dry is considerably younger than the Finis, though both belong in the Upper Pennsylvanian series. Furthermore the sediments which compose the Dry shale may have been deposited in waters of abnormal salinity, for presumably they accumulated near the northern terminus of an Upper Pennsylvanian cul-de-sac. The fact that the specimens are now limonitic suggests that originally they may have been preserved in pyrite, and it has been generally held that animals living in water containing a sufficient amount of iron compounds are likely to be inhibited in their growth.

No other ammonoid faunas are known from North Ame:ica that are at all similar to that of the Finis shale, and it has been contended that in other parts of the world beds of this general age are almost devoid of ammonoids. However, Ruzhencev (1936, pp. 505–506; 1939, p. 850; 1945, p. 289) has stated that in the Orenburgian of the Ural region he has discovered "a rich and highly characteristic fauna of ammonites with such typical Upper Carboniferous genera as *Uddenites, Vidrioceras, Shumardites, Marathonites* [=*Petritrochia*], *Emilites, Schistoceras, Glaphyrites* [=*Eoasianites*], *Aristoceras* [=*Eothalassoceras*], *Neodimorphoceras*, etc." Representatives of certain of these genera (*Uddenites, Schistoceras*, and *Neodimorphoceras*) have never been illustrated or described from the Ural region, but Ruzhencev's list is certainly suggestive of the fauna of the Finis shale. Furthermore, it indicates that, as he pointed out, the view should no longer be held that development of highly complex ammonoids of the Permian from the relatively simple forms of the Upper Carboniferous or Pennsylvanian almost certainly took place in the area that is now the southwestern United States.

SYSTEMATIC PALEONTOLOGY

Genus UDDENITES Böse, 1919

Genotype.—Uddenites schucherti Böse.

During early ontogenetic development,

typical representatives of this genus pass through a *Pronorites* and then a *Prouddenites* stage, but there is a considerable amount of individual variation in the sutures of each of the several specimens that have been studied in detail. At maturity, the sutures of the genotype of *Uddenites* are only slightly more advanced than those of the type species of *Prouddenites*, but the two genera can also be differentiated by the fact that the conch of the former is grooved ventrally, whereas that of *Prouddenites* is not. Advanced representatives of *Uddenites* have sutures that approach those of *Propinacoceras*, and there is more or less gradation from the single known species of *Prouddenites* through *Uddenites* to *Propinacoceras*.

Miller and Furnish (1940, pp. 37–38) concluded that of the several species of *Uddenites* which have been proposed, *U. minor* Böse and possibly *U. serratus* Plummer and Scott are to be suppressed as synonyms of *U. schucherti*, and *U. subschucherti* Plummer and Scott (a *nomen nudum*) is probably a synonym of *U. oweni* Miller and Furnish, which appears to be fairly close to *U. harlani* Plummer and Scott. The last is based on a large specimen and is said to be characterized by the possession of "distinct and regular" ventrolateral nodes, whereas even large testiferous representatives of *U. oweni* are not prominently nodose (see pl. 31, figs. 3, 4). The conch of *U. schucherti* is relatively wider than that of *U. oweni* and *U. harlani*, but intermediate forms may be found.

Representatives of the genus *Uddenites* are known only from the Upper Pennsylvanian of Texas and probably the upper Uralian of the southern Urals (Ruzhencev, 1936, p. 484; 1939, p. 850; 1945, p. 289). In west Texas they occur in the upper part of the Gaptank formation, and in the north-central portions of the same state they have been found in the Caddo Creek and Graham formations (uppermost Canyon and basal Cisco, respectively).

UDDENITES OWENI Miller and Furnish
Plate 31, figures 1–6

Uddenites schucherti [part] SMITH, 1929, Am. Jour. Sci., 5th ser., vol. 17, pp. 67, 71, 72–75; text figs. A1–A13; ? KING, 1930, Jour. Paleontology, vol. 4, p. 387; ? MILLER, 1930, *idem*, vol. 4, pp. 400–401, pl. 39, figs. 17–19; PLUMMER, 1937, Am. Jour. Sci., 5th ser., vol. 33, p. 465; [part] PLUMMER and SCOTT, 1937, Texas Univ. Bull. 3701, pp. 17, 18, 19, 34?, 64, 67–69, 70, 71, 361, 380, 382, 394, 399, text fig. 88 (opp. p. 402), pl. 3, figs. 4–8, 9?, 10 [not 1–3].

? *Uddenites* sp., SCOTT and ARMSTRONG, 1932, Texas Univ. Bull. 3224, p. 39.

? *Uddenites subschucherti* PLUMMER and SCOTT, 1937, Texas Univ. Bull. 3701, text fig. 88 (opp. p. 402).

Uddenites oweni MILLER and FURNISH, 1940, Geol. Soc. America Special Paper 26, pp. 12, 36, 37, 38, pl. 2, figs. 1, 2, 5, 6; pl. 3, figs. 9, 10.

The literature contains several detailed descriptions of specimens that belong in this species, and there is no need for us to duplicate that work. However, some of the individuals in our collections show that the phragmacone attains a diameter of at least 40 mm. and that the living chamber is at least a quarter of a volution in length. The width of the conch seems to be somewhat variable and is affected by lateral crushing which many of the specimens have undergone. In the small internal mold represented by figures 5 and 6 on plate 31, it can be seen that the ventral groove, which is so characteristic of this genus, develops rather gradually, starting when the conch has attained a diameter of about $7\frac{1}{2}$ mm.

As shown by figure 3 on plate 31, at full maturity the flat ventral zones which border the median ventral groove bear transverse nodes or short ribs, and traces of these can be discerned on the internal mold in many specimens. Testiferous specimens show that the growth lines are fairly prominent on the lateral zones of the conch, where they are sigmoidal, forming broad rounded sinuses on the ventral half of those zones and similar but somewhat smaller salients on the dorsal half (pl. 31, fig. 4).

The shape of the sutures during late adolescence and at full maturity is shown by text figure 1. Additional suture drawings were published by Smith in 1929, Plummer and Scott in 1937, and Miller and Furnish in 1940.

Remarks.—The numerous specimens that we are referring to this species show a considerable amount of variation, particularly with respect to the relative width of the ventral groove and the ventral zones on either side of it, the ventral nodes or short ribs, and the smaller inflections of the sutures. However, there is so much individual variation in these details that we are

inclined to believe that they have little taxonomic significance. Furthermore, they are greatly affected by preservation and interpretation, and especially by crushing and distortion of the conch during fossilization.

On the legend of their plate 3 of 1937, Plummer and Scott inadvertently designate as the holotype of *U. schucherti* Böse a specimen that belongs in *U. oweni*. That specimen came from the Graham formation of north-central Texas; it was not among Böse's original types which came from the Gaptank formation of west Texas, and it can therefore not be established as the holotype of the species.

Occurrence.—Locally this species is not rare in the Graham formation of north-central Texas and in the upper part of the Gaptank formation of west Texas. In the Graham it occurs in two members, the Finis and the Wayland shales. We have representatives of it from the Finis at the following localities, all in Jack County: (1) the Ramzy and Riley ranches about 3½ miles east of Jacksboro, (2) west side of highway about 4 miles south of the same town, and (3) about 4½ miles southwest of Jacksboro. Also, this species is almost certainly represented by a specimen from an exposure of the same shale in a cut along the Rock Island Railroad just east of the viaduct on the Mineral Wells-Jacksboro highway about 3½ miles southeast of Jacksboro.

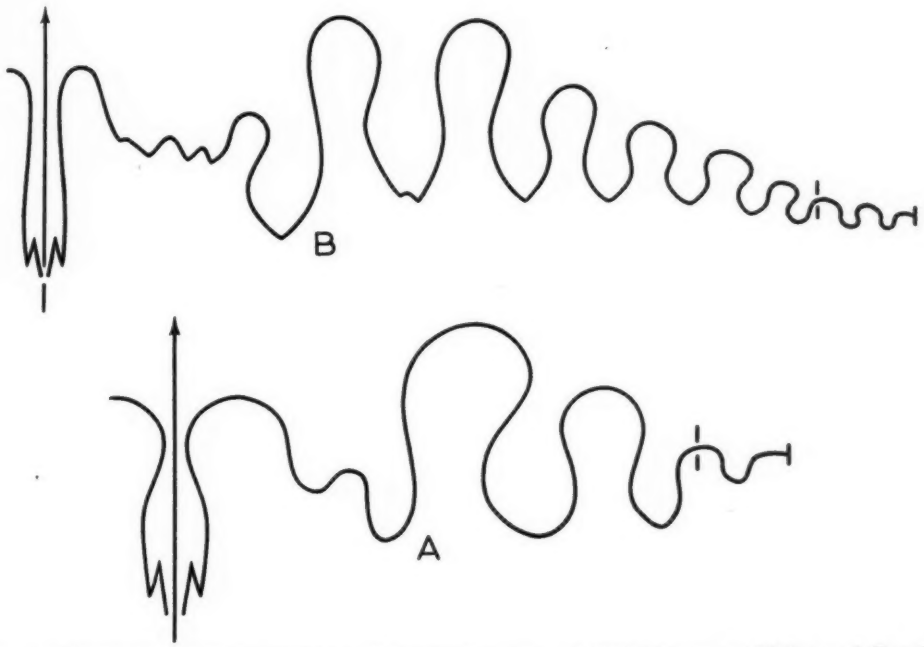

FIG. 1—Diagrammatic representations of external sutures of *Uddenites oweni* Miller and Furnish, based on the specimen represented by figures 1 and 2 on plate 31, where the conch is about 3 mm. and 13½ mm. high, ×25 and ×6, respectively.

Repositories.—State University of Iowa, 13604 (pl. 31, figs. 5, 6); U.S. National Museum (pl. 31, figs. 1, 2); and private collection of James P. Conlin of Fort Worth, 3581 (pl. 31, figs. 3, 4). Additional specimens are present in the first and the last of these collections and in those at the University of Texas.

Genus IMITOCERAS Schindewolf, 1923

Genotype.—*Ammonites rotatorius* de Koninck.

In typical mature representatives of this genus, the conch is subdiscoidal, the umbilicus is small and closed, and the sutures

are rather primitive and consist of eight undivided pointed lobes separated by rounded saddles. However, some of the species that are now placed in the genus have rather wide conchs, some have moderately large umbilici, and in one the ventral and external lateral lobes of the sutures are not pointed. In the eastern hemisphere, the genus (as we are interpreting it) appears in the Upper Devonian and ranges up into the Middle Permian (Sosio beds of Sicily). In North America it was formerly thought to be limited to the Kinderhook group, but it is now known to occur in our Osagian strata and in various portions of our Pennsylvanian system.

Typical *Imitoceras* is at least superficially similar to *Gattendorfia* Schindewolf, 1920, and *Prionoceras* Hyatt, 1884 [=*Postprolobites* Wedekind, 1913]. However, Schindewolf placed these two latter genera in the family Prolobitidae Wedekind, 1913, whereas he referred *Imitoceras* to the Cheiloceratidae Frech, 1897, a procedure that has been questioned by Librovitch (1940, p. 227). These two families are stated to differ in the nature of the growth lines and constrictions and in the development of certain elements of the sutures, which can not be studied satisfactorily in many specimens.

This genus, as now interpreted, contains most of the species that have in the past been referred by American authors to *Aganides* de Montfort, 1808, and *Branconceras* Hyatt, 1884. As explained by Schindewolf (1923, pp. 325–329) and by Miller and Werner (1942, pp. 479–480) the latter of these generic names was preoccupied; and the former, though valid, is quite useless, for it does not seem to be possible to determine the nature of the form for which it was originally used.

In 1937, Plummer and Scott proposed the generic name *Neoaganides* for a single species of small ammonoids from the Upper Pennsylvanian Graham formation of north-central Texas, *N. grahamensis* P. and S. However, they did not compare this form with typical representatives of *Imitoceras* or any other genus. Two years later, Miller and Owen (1939, p. 146–147) correctly pointed out that the sutures of the genotypes of both *Neoaganides* and *Imitoceras* consist of the same number of elements in about the same general proportions and arrangement. Therefore, if both genera are to be recognized, they will probably have to be differentiated on the basis of ontogeny, the shape of the growth lines, or the size of the conch. It seems very doubtful that the ontogeny of the two forms is appreciably different, and the shape of the growth lines is of uncertain value. In general, size is hardly a valid generic distinction. However, it is worthy of note that all known Pennsylvanian and Permian forms that have simple sutures like those of the genotype of *Imitoceras* are less than 15 mm. in diameter, whereas most of the Lower Mississippian and Upper Devonian forms attain a much larger size. It may be therefore, that the Pennsylvanian and Permian forms are degenerate representatives of an entirely different stock (or stocks) and therefore generically distinct

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EXPLANATION OF PLATE 31

All specimens are from the Finis shale of north-central Texas.

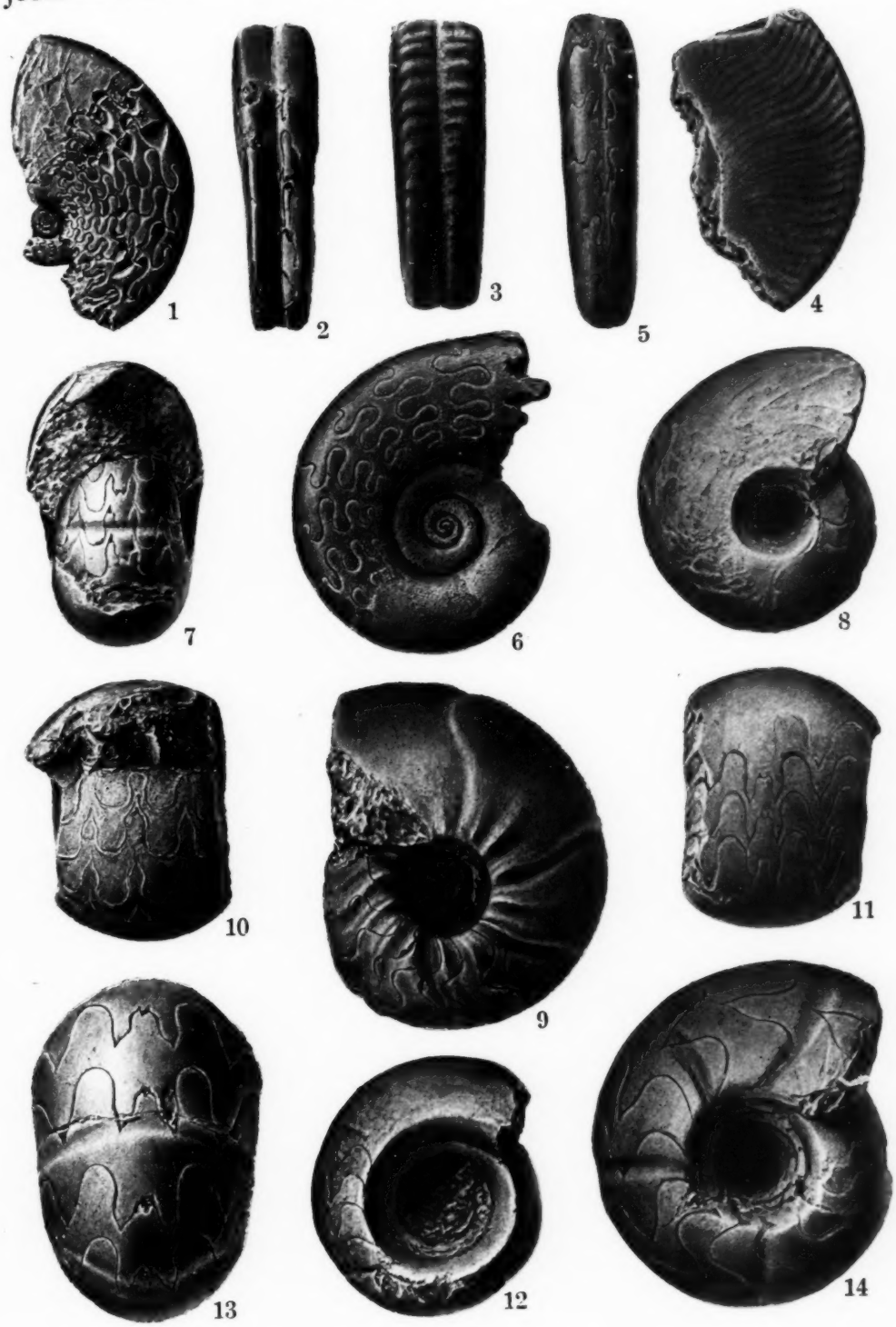
FIGS. *1–6—Uddenites oweni* Miller and Furnish. *1–4*, Two specimens from about 3½ miles east of Jacksboro, Texas, ×1½. *1, 2* (U.S.N.M.); *3, 4*, (J.P.C. 3581). *5, 6*, specimen from about 4 miles south of the same town, (S.U.I. 13604), ×5. Figs. *1–4* show the nature of the sutures and the surface ornamentation of the test at full maturity; *5* and *6* represent the transition from late adolescence to early maturity and show the development of the ventral groove. (p. 190)

7, 8—Eoasianites anguloumbilicatus (Plummer and Scott). An almost complete specimen (S. U. I 1070) from 4 miles east-northeast of Jacksboro, ×1½. (p. 203)

9—Goniolobоceras goniolobum (Meek). An early adolescent individual (R. J. S.) from about 3½ miles east of Jacksboro, ×8. (p. 196)

10–12—Eoasianites millsi (Miller and Cline)? A phragmacone (J. P. C. 3699) showing both the internal (fig. 10) and the external (fig. 11) sutures, from the same locality as the preceding, ×1½. (p. 204)

13, 14—Eoasianites modestus (Böse). A medium-sized specimen (J. P. C. 3707), from the same locality as figure 9, ×1½. (p. 205)



Miller and Downs, Pennsylvanian ammonoids

Miller and Downs, Pennsylvanian ammonoids

from typical *Imitoceras*. Nevertheless, it seems to us that for the present at least, it is best to refer all of the Late Paleozoic forms with similar sutures to *Imitoceras*.

IMITOCERAS GRAHAMENSE (Plummer and Scott)
Plate 32, figures 1–4

Aganides? sp. ELIAS, 1936, Internat. Geol. Cong., Rept. 16th sess., vol. 1, p. 695.
Neoaganides grahamensis PLUMMER and SCOTT 1937, Texas Univ. Bull. 3701, pp. 18, 350–351, 390, 502, text fig. 88 (opp. p. 402), pl. 40, figs. 4–9.
Imitoceras grahamense MILLER and OWEN, 1939, Jour. Paleontology, vol. 13, pp. 146–147, text fig. 2, pl. 20, figs. 18–20; MILLER and UNKLESBAY, 1943, *idem*, vol. 17, pp. 11–12; SHIMER and SHROCK, 1944, Index fossils of North America, p. 573, pl. 234, figs. 18, 19.

Conch small (attaining a maximum diameter of only about 10 mm.), thickly subdiscoidal, whorls flattened (but nevertheless very broadly rounded) laterally, rather narrowly rounded ventrally, and deeply impressed dorsally. The moderately large specimen represented by figures 1 and 2 on plate 32 is about 6.8 mm. in diameter, and at its adoral end its conch is about 3.7 mm. high and 4 mm. wide. Corresponding measurements of the specimen represented by figures 3 and 4 on the same plate are about 5 mm., 3 mm., and 3 mm., respectively. A comparison of these two sets of figures makes it clear that during ontogenetic development the conch becomes relatively somewhat higher and narrower. The living chamber is at least three-fifths of a volution in length. The umbilicus is small, inconspicuous, and closed, and the umbilical shoulders are rounded and indefinite.

The test appears to be thin and almost smooth. However, in the adoral portion of large, fully mature specimens, the lateral zones of at least the internal mold bear faint transverse undulations which form shallow lateral sinuses and which curve rather strongly apicad on the ventrolateral zones, suggesting that there was a moderately deep sinus there (which, however, is not discernible).

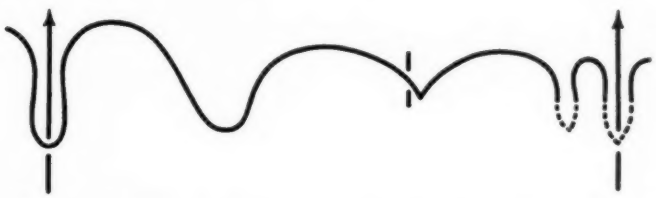


FIG. 2—Diagrammatic representation of an adoral suture (at a diameter of about 4 mm.) of a mature specimen (U. S. N. M.) from the Finis shale about 4½ miles east of Jacksboro, ×20.

As shown by text figure 2, each mature suture forms a rather narrow spatulate rounded ventral lobe and on either side of it a much broader rounded first lateral saddle, a V-shaped but narrowly rounded first lateral lobe, a broad rounded second lateral saddle, a small asymmetrical subangular

EXPLANATION OF PLATE 32

All specimens are from the Finis shale of north-central Texas except that illustrated by figures *1* and *2*, which is from the Wayland shale, slightly higher in the Graham formation.

FIGS. *1–4*—*Imitoceras grahamense* (Plummer and Scott). Two internal molds of mature individuals. *1, 2*, (S.U.I. 3299), From about 5 miles north of Jacksboro, Texas; *3, 4*, (U.S.N.M.), from about 4½ miles east of the same town. All ×10. (p. 193)
5–9—*Goniloboceras goniolobum* (Meek). Three internal molds. *5, 6*, (S.U.I. 13809), From 3½ miles southeast of Jacksboro, Texas; *7–9*, (J.P.C. 3681 and 3663, respectively), from 3½ miles due east of the same town. *5, 6, 9*, ×1; *7, 8*, ×2. (p. 196)
10, 11—*Neodimorphoceras texanum* (Smith). A large internal mold (S. U. I. 13829) from 3½ miles east of Jacksboro, ×1. (p. 200)

umbilical lobe, a broad rounded internal second lateral saddle, a small narrow internal first lateral lobe, and a rather small U-shaped internal first lateral saddle which extends to the rather narrow dorsal lobe—the exact size and shape of the adapical portions of the internal lobes are not shown by any of the specimens in the collections we are studying. As in many cephalopods, the adoral camerae of fully mature individuals are shorter than the preceding ones.

Remarks.—All of the many specimens that we are placing in this species, regardless of the locality from which they came, are preserved as limonitic internal molds. The only closely similar form that has been described previously is *I. cherokeense* Miller and Owen from the Lower Pennsylvanian of west-central Missouri. That species is, however, readily distinguished by the fact that the distal end of the ventral lobe of its sutures is concave apicad rather than convex.

Occurrence.—Finis shale about 4½ miles east of Jacksboro in Jack County, Texas (pl. 32, figs. 3, 4; and text fig. 2). Also, according to Plummer and Scott this species occurs in the "shale at the bottom of the Graham formation," that is, the Finis, in the Rock Island Railroad cut about 3½ miles southeast of Jacksboro. Furthermore, the collections available to us contain conspecific specimens from the Wayland shale member of the Graham formation at the following localities in north-central Texas: (1) about 5 miles north of Jacksboro (pl. 32, figs. 1, 2), (2) about 6½ miles northwest of the same town and (3) an eighth of a mile north-northeast of the Weedon School in Brown County. According to Plummer and Scott the Wayland shale also yielded this species at the following two north-central Texas localities: (1) about 1½ miles east of Caddo in Stephens County and (2) half a mile southwest of South Bend in Young County; and they stated (p. 351) that the "species is fairly abundant at most ammonite localities in the Graham formation." Finally, the collections of the State University of Iowa contain many conspecific specimens from the Dry shale (just above the Dover limestone) of the Wabaunsee group at several localities near Piedmont in Greenwood County and particularly near Emporia in Lyons County, Kansas; and one crushed questionable representative of the species from the Nellie Bly formation about 6½ miles due west of Sand Springs, Tulsa County, Oklahoma. Altogether the species is, then, now known to occur in the Finis and Wayland shale members of the Graham formation of north-central Texas, the upper part of the Wabaunsee group of eastern Kansas, and probably the Skiatook group of northeastern Oklahoma.

[After this discussion was written, Mr. John B. Carrier of The Superior Oil Company sent us a pyritized representative of this species (S.U.I. 8023) from the Superior No. 33-18 Cogdill well in the Anadarko basin, NW¼ SE¼ NW¼ sec. 18, T. 8 N., R. 11 W., Caddo County, Oklahoma. It came from a depth of 7210 feet in a sandstone and shale sequence which is believed to be the Niles "formation" (about lower Shawnee).]

Repositories.—U.S. National Museum (pl. 32, figs. 3, 4; and text fig. 2); State University of Iowa, 3299 (pl. 32, figs. 1, 2), and numerous specimens from the Wayland shale of north-central Texas and the Dry shale of Kansas. The primary types are in the Plummer collection at the University of Texas.

Genus GONIOLOBOCERAS Hyatt, 1900

Genotype.—Goniatites goniolobum Meek.

This genus was established for a species known at the time from only a single specimen obtained at some unrecorded horizon and locality in New Mexico. The holotype has unfortunately been lost, but hundreds of similar specimens have been collected; and the genus is now known to be a fairly well defined biological unit which is of widespread occurrence in our Pennsylvanian strata and is probably represented also in the Carboniferous of northern Africa and possibly that of Middle Asia.

From a study of the published data in regard to the original type and the African and Asiatic forms and an examination of several hundred specimens from various horizons and localities in the Pennsylvanian of this country, we have drawn up the following diagnosis of the genus:

Conch subdiscoidal, attains a fairly large size; whorls strongly compressed, very slightly convex laterally, deeply impressed dorsally, and narrowly rounded ventrally—

at full maturity the median portion of the ventral zone is distinctly flattened. Umbilicus small and inconspicuous but apparently not closed. Test thin and marked only by growth lines, each of which forms rounded ventral and lateral sinuses and ventrolateral and prominent dorsolateral salients. Each suture consists of eight lobes and an equal number of saddles—all of the lobes but the ventral one (which is very large and bifid) are pointed, and all of the saddles but the first lateral one are rounded (see text fig. 3A). In North America *Goniolobоceras* is known to be represented in New Mexico, Texas, Oklahoma, Kansas, Missouri, and Illinois; and stratigraphically it seems to range throughout most of our Pennsylvanian system. The African specimens which have been referred to this genus (Delépine, 1941, pp. 98–99) are from the lower Westphalian of the Djerada Basin of northeastern Morocco. The Asiatic ones (Librovitch, 1940, pp. 326–329) all came from the Karaganda coal district in northern Kazakhstan—the age of the Carboniferous beds which yielded them is uncertain, and so are their generic affinities.

As is now generally recognized, the genotype of *Milleroceras* Hyatt, 1900 (*Goniatites parrishi* Miller and Gurley of the Middle Pennsylvanian of Kansas City, Missouri) is not generically or even specifically distinct from typical *Goniolobоceras*. Both of these names were proposed by Hyatt (1900, pp. 550, 551) on successive pages of the same publication. Although *Milleroceras* has page precedence, we are retaining *Goniolobоceras* because usage has probably established a preference for it.

Gurleyoceras Miller, 1936, was proposed for *Goniolobоceras*-like forms with a retuse ventral zone, and *Goniolobоceras welleri* Smith of the Pennsylvanian of Texas and Illinois was designated as its genotype. Although Smith (1903, p. 125, pl. 21, fig. 4) indicated that in mature representatives of this species the "venter [is] narrow, angular, and slightly furrowed," Plummer and Scott (1937, pp. 332, 336–337) and Elias (1938, p. 95) have shown that this is not the case; and most probably, as suggested by Plummer and Scott, Smith "must have confused, *Goniolobоceras welleri* with a nonseptate specimen of *Neodimorphoceras texanum* (Smith) which occurs with it and is similar in outward appearance except for its grooved venter." *Gurleyoceras* is therefore to be suppressed as a synonym of *Goniolobоceras*. Plummer and Scott then proposed the name *Gonioglyphioceras* for the ventrally grooved forms Miller had in mind and designated as its genotype *Goniolobоceras welleri gracile* Girty of the Wewoka formation of Oklahoma. This solution of the matter seems to us to be entirely satisfactory, but as Miller and Sturgeon (1946, p. 385) have pointed out, in some Wewoka specimens "the ventral furrow is largely, if not entirely, confined to the test, and not more than a trace of it is retained on the internal mold."

At least superficially, typical mature *Goniolobоceras* resembles adolescent stages of the genotype of *Girtyoceras* Wedekind, 1918, *Adelphoceras meslerianum* Girty of the Caney shale of Oklahoma and beds presumably of about the same age in Texas, Nevada, Montana, Kentucky, Georgia, and probably various localities in England and western Europe. However, those small representatives of that species bear prominent sinuous transverse constrictions (as does immature *Goniolobоceras*), and at full maturity the ventral zone of their conchs becomes angular. It should not be thought that *Girtyoceras* is ancestral to *Goniolobоceras*, which most probably evolved from *Wiedeyoceras* Miller, 1932, whose type species, *Eumorphoceras sanctijohanis* Wiedey, is from the lower Cherokee of central Iowa.

The specimens from the Carboniferous of Kazakhstan that Librovitch referred to *Goniolobоceras* bear constrictions throughout ontogenetic development, and they may be more closely related to the genotype of *Girtyoceras* than to that of *Goniolobоceras*. However, the ventral zone of their conchs remains rounded throughout ontogenetic development, as in *Goniolobоceras*. Except in size, mature specimens of these Asiatic forms are very similar to late adolescent representatives of *Girtyoceras* and somewhat earlier stages of *Goniolobоceras*, and therefore it seems likely that the beds which carry them are Lower (rather than Upper) Carboniferous in age. Only two fragments are known of the Moroccan form that has been referred to *Goniolobоceras;* but Delépine's illustrations and description of it in-

dicate that he is correct in his belief that it is close to *G. eliasi* Miller and Owen of the Cherokee of Missouri, though its sutures seem to suggest that it may be a little more primitive—its age is stated to be lower Westphalian.

In 1935, when Yin (p. 31) established *Shuichengoceras*, he regarded it as a subgenus of *Goniloboceras*. The only known species *G.* (*S.*) *yohi* Yin, of the Lower Permian? of central China, seems to be quite similar to typical representatives of *Goniloboceras*, but the "prongs" of the ventral lobe of its sutures are asymmetrically bifid. In our opinion, this difference is of sufficient taxonomic value to separate the two generically, and as Miller and Owen (1939, p. 160) have suggested, Yin's type species is "more or less intermediate between typical *Dimorphoceras* and typical *Neodimorphoceras*."

GONIOLOBOCERAS GONIOLOBUM (Meek)

Plate 31, figure 9; plate 32, figures 5–9

Goniatites goniolobus MEEK, 1877, U. S. Geol. Explor. Fortieth Parallel (King), vol. 4, pp. 98–99, pl. 9, figs. 5–5b; ABICH, 1878, Geol. Forsch. kaukasischen Ländern, Theil 1, pp. 120–122, text fig. 7; KNIGHT, 1900, Wyoming Univ., Wyoming Exp. Sta. Bull. 45, pl. 3, fig. 8.

Goniatites sp.? KEYES, 1894, Missouri Geol. Survey, vol. 5, pl. 56, fig. 1.

Goniatites parrishi MILLER and GURLEY, 1896, Illinois State Mus. Nat. Hist. Bull. 11, p. 36, pl. 4, figs. 6–8.

Milleroceras parrishi HYATT, 1900, Zittel-Eastman Text-book of palaeontology, vol. 1, p. 550; SMITH, 1903, U. S. Geol. Survey Mon. 42, pp. 15, 127–128, 146, pl. 16, figs. 6–8; MILLER, 1932, Jour. Paleontology, vol. 6, pp. 69–70, 72–73, text fig. 1B, pl. 12, figs. 5–7; PLUMMER and SCOTT, 1937, Texas Univ. Bull. 3701, pp. 328, 329–330, pl. 33, figs. 12, 13.

Goniloboceras goniolobum HYATT, 1900, Zittel-Eastman Text-book of palaeontology, vol. 1, p. 551; SMITH, 1903, U. S. Geol. Survey Mon. 42, pp. 123–124, 125, 146, pl. 4, figs. 1–3; GRABAU and SHIMER, 1910, North American index fossils, Invertebrates, vol. 2, p. 140; SMITH, 1913, Zittel-Eastman Text-book of paleontology, vol. 1, ed. 2, p. 631; GIRTY, 1915, U. S. Geol. Survey Bull. 554, pp. 261, 262; BÖSE, 1920, Am. Jour. Sci., 4th ser., vol. 49, pp. 52, 54; SCHMIDT, 1929, Tierische Leitfossilien des Karbon, Gürichs Leitfossilien, Lief. 6, p. 75; SMITH, 1929, Am. Jour. Sci., 5th ser., vol. 17, p. 67; SAYRE, 1930, Kansas Univ. Sci. Bull., vol. 19, pt. 2, pp. 82, 157, pl. 21, fig. 5; ——, 1931, *idem*, 17, pp. 82, 157, pl. 21, fig. 5; MILLER, 1932, Jour. Paleontology, vol. 6, p. 76, text fig. 1C; —— and CLINE 1934, *idem*, vol. 8, p. 176; YIN, 1935, Palaeont. Sinica, ser. B, vol. 11, fasc. 4, p. 30; ELIAS, 1936, Internat. Geol. Cong., Rept. 16th sess., vol. 1, p. 694; PLUMMER and SCOTT, 1937, Texas Univ. Bull. 3701, pp. 33, 331, 333, 334, pl. 34, figs. 6–8; ELIAS, 1938, Jour. Paleontology, vol. 12, pp. 91, 93, 94, 96, 97, 98–99, 100, text figs. 1L–1M^{6}, pl. 20, figs. 1–3b; MILLER and OWEN, 1939, *idem*, vol. 13, p. 157; LIBROVITCH, 1940, U. S. S. R. Acad. Sci., Paleont. Inst., Paleontology of U. S. S. R., vol. 4, pt. 9, fasc. 1, pp. 167, 168, 170, 173, 174, 175, 176, 177, 182, 194, 216, 299, 300, 304, 327, pl. 24, figs. 2a–2c; SHIMER and SHROCK, 1944, Index fossils of North America, p. 571, pl. 234, figs. 24, 25.

Goniloboceras welleri SMITH, 1903, U. S. Geol. Survey Mon. 42, pp. 15, 16, 125–126, 138, 146, pl. 20, figs. 9–11, pl. 21, figs. 1–6; GRABAU and SHIMER, 1910, North American index fossils, Invertebrates, vol. 2, p. 140, text figs. 1392a–1392c; GIRTY, 1911, New York Acad. Sci. Ann., vol. 21, p. 154; ——, 1915, U. S. Geol. Survey Bull. 544, pp. 262, 263, 264; BÖSE, 1920, Am. Jour. Sci., 4th ser., vol. 49, pp. 52, 53, 54; PLUMMER and MOORE, 1922, Texas Univ. Bull. 2132, pp. 84, 120, 150, 220, pl. 25, fig. 7; SMITH, 1927, U. S. Geol. Survey Prof. Paper 141, pl. 20, figs. 1–3; ——, 1929, Am. Jour. Sci., 5th ser., vol. 17, p. 67; ——, 1932, U. S. Geol. Survey Prof. Paper 167, p. 23, pl. 43, figs. 1–3; SELLARDS, 1932, Univ. Texas Bull. 3232, p. 114; YIN, 1935, Palaeont. Sinica, ser. B, vol. 11, fasc. 4, p. 30; ELIAS, 1936, Internat. Geol. Cong., Rept. 16th sess., vol. 1, pp. 694, 695; PLUMMER, 1937, Am. Jour. Sci., 5th ser., vol. 33, p. 465; —— and SCOTT, 1937, Texas Univ. Bull. 3701, pp. 18, 29, 30, 33, 326, 328, 330, 331–333, 334, 335, 336, 337, 399, text fig. 88 (opp. p. 402), pl. 33, figs. 10, 11, pl. 34, figs. 1–5; ELIAS, 1938, Jour. Paleontology, vol. 12, pp. 90, 91, 93, 94–97, 98, 99, 100, text figs. 1A–1K, pl. 19, figs. 1–8c, pl. 20, figs. 6a, 6b; WILLIAMS, 1938, Texas Univ. Publ. 3801, pp. 169, 170, 180, 181, 185, 188, 191, 225; MILLER and OWEN, 1939, Jour. Paleontology, vol. 13, pp. 157, 158; LIBROVITCH, 1940, U. S. S. R. Acad. Sci., Paleont. Inst., Paleontology of U. S. S. R., vol. 4, pt. 9, fasc. 1, pp. 168, 170; DELÉPINE, 1941, Protect. l'État Français Maroc, Direct. Gén. Trav. Pub., Div. Mines et Géol., Serv. Géol., Notes et Mém., no. 56, p. 99; MILLER and UNKLESBAY, 1943, Jour. Paleontology, vol. 17, pp. 15–16, text figs. 5A, 9F, pl. 1, fig. 4; SHIMER and SHROCK, 1944, Index fossils of North America, p. 573, pl. 234, figs. 22, 23.

Goniloboceras parrishi GIRTY, 1915, U. S. Geol. Survey Bull. 544, pp. 261–262; ——, 1915, Missouri Bur. Geol. and Mines, 2d ser., vol. 13, p. 364; SAYRE, 1930, Kansas Univ. Sci. Bull., vol. 19, pt. 2, p. 82; ——, 1931, Kansas Geol. Survey, vol. 17, p. 82; YIN, 1935, Palaeont. Sinica, ser. B, vol. 11, fasc. 4, p. 30;

MILLER and OWEN, 1939, Jour. Paleontology, vol. 13, p. 157.

Goniloboceras discoidale BÖSE, 1920, Am. Jour. Sci., 4th ser., vol. 49, pp. 52–54; SMITH, 1929, Am. Jour. Sci., 5th ser., vol. 17, p. 67; LIBROVITCH, 1940, U. S. S. R. Acad. Sci., Paleont. Inst., Paleontology of U. S. S. R., vol. 4, pt. 9, fasc. 1, pp. 167, 168.

Gurleyoceras discoidale, MILLER, 1932, Jour. Paleontology, vol. 6, pp. 61, 75, 77–79, pl. 12, figs. 14–16.

Gurleyoceras welleri MILLER, 1932, Jour. Paleontology, vol. 6, pp. 61, 76, 78.

Milleroceras minusculum MILLER, 1932, Jour. Paleontology, vol. 6, pp. 70, 73–74, pl. 12, figs. 8–11.

Wiedeyoceras nodomarginatum MILLER, 1932, Jour. Paleontology, vol. 6, pp. 80–82, 83, pl. 13, figs. 6–8.

? *Goniloboceras* sp. SCOTT and ARMSTRONG, 1932, Texas Univ. Bull. 3224, p. 25; PLUMMER and SCOTT, 1937, Texas Univ. Bull. 3701, p. 17.

Goniloboceras gracellenae MILLER and CLINE, 1934, Jour. Paleontology, vol. 8, pp. 175–176, pl. 28, figs. 14–18; PLUMMER, 1937, Am. Jour. Sci., 5th ser., vol. 33, p. 464; —— and SCOTT, 1937, Texas Univ. Bull. 3701, pp. 331, 333–334, 335, 336, 387, 388, 399, text fig. 88, pl. 33, figs. 5–9; LIBROVITCH, 1940, U. S. S. R. Acad. Sci., Paleont. Inst., Paleontology of U. S. S. R., vol. 4, pt. 9, fasc. 1, pp. 169, 170 171, 176, 182, 216, 300, 304, 327; MOORE *et al.*, 1944, Geol. Soc. America Bull., vol. 55, pp. 678, 698.

Wiedeyoceras pingue MILLER and CLINE, 1934, Jour. Paleontology, vol. 8, pp. 178–179, pl. 28, figs. 4–6; PLUMMER and SCOTT, 1937, Texas Univ. Bull. 3701, pp. 17, 18, 33, 177–178, 390, text fig. 88 (opp. p. 402), pl. 13, figs. 12–18.

Goniloboceras welleri gracile BULLARD and CUYLER, 1935, Texas Univ. Bull. 3501, p. 227.

? *Goniloboceras bridgeportense* PLUMMER and HORNBERGER, 1936, Texas Univ. Bull. 3534, p. 52 [*nomen nudum*]; PLUMMER and SCOTT, 1937, Texas Univ. Bull. 3701, pp. 17, 33, 331, 333, 334, 335–336, pl. 33, figs. 1–4; DELÉPINE, 1941, Protect. l'État Français Maroc, Direct. Gén. Trav. Pub., Div. Mines et Géol., Serv. Géol., Notes et Mém., no. 56, p. 99.

Goniloboceras (*Milleroceras*) *minusculum* LIBROVITCH, 1940, U. S. S. R. Acad. Sci., Paleont. Inst., Paleontology of U. S. S. R., vol. 4, pt. 9, fasc. 1, pp. 168, 169, 170, 171, 172, 189, 217, 309, 327.

Goniloboceras (*Milleroceras*) *parrishi* LIBROVITCH, 1940, U. S. S. R. Acad. Sci., Paleont. Inst., Paleontology of U. S. S. R., vol. 4, pt. 9, fasc. 1, pp. 167, 168, 170, 189, 217, 310, 327.

Anthracoceras multilineatum YOUNG, 1942, Jour. Paleontology, vol. 16, p. 125, pl. 20, fig. 13.

Conch large and subdiscoidal. Phragmacone attains a diameter of at least 80 mm., and fragments that seem to represent the living chamber indicate that it was at least a quarter of a volution in length and that the complete conch of large individuals was considerably more than 100 mm. in diameter. None of the many phragmacones available to us retains even a portion of the living chamber. The whorls are strongly compressed, rather narrowly rounded (but at full maturity medianly flattened) ventrally, very broadly rounded laterally, and deeply impressed dorsally. The phragmacone attained a maximum height of conch of at least 48 mm. and a corresponding maximum width (just outside the umbilical shoulders) of some 24 mm. and depth of impressed zone of about 21 mm. The lateral zones converge ventrad.

The umbilicus is small and inconspicuous but not closed. The umbilical shoulders are rounded and indefinite, and the umbilical walls are steep.

The test is thin and at maturity is marked only by the growth lines. Each of them forms rounded ventral and lateral sinuses and ventrolateral and dorsolateral salients; the ventrolateral salients are much more prominent and more narrowly rounded than are the dorsolateral ones, and the latter are located outside the umbilical shoulders.

During early ontogenetic development, at least the internal mold bears prominent transversely elongate umbilical nodes and sinuous transverse constrictions (pl. 31, fig. 9). Only a few early adolescent specimens from the Finis shale are available for study, and all of them but the one we are figuring is crushed. However, several authors have reported on many similar specimens from various horizons in the Upper Pennsylvanian of Texas, New Mexico, Oklahoma, and Kansas—some of these have been referred to *Goniloboceras* and others to *Wiedeyoceras*. The collections at the State University of Iowa contain a great many small limonitic internal molds from the Wayland shale of Texas, the Nellie Bly formation of Oklahoma, and the Dry shale of Kansas; and they make it clear that the forms which in 1932 Miller called *W. nodomarginatum* and those which in 1934 Miller and Cline and in 1937 Plummer and Scott termed *W. pingue* are in reality immature representatives of *G. goniolobum*. That is, some of the larger of these specimens show that both the nodes and the constrictions tend to cease abruptly at a diameter of

some 5 to 7 mm. (though faint ones may be formed somewhat orad of there), and then the sutures gradually assume the shape that has in the past been regarded as characteristic of *Milleroceras*, a generic term now known to have been proposed for late adolescent specimens of *G. goniolobum*. It should also be stated that the early volutions of the conch are relatively wider than those formed after maturity had been attained.

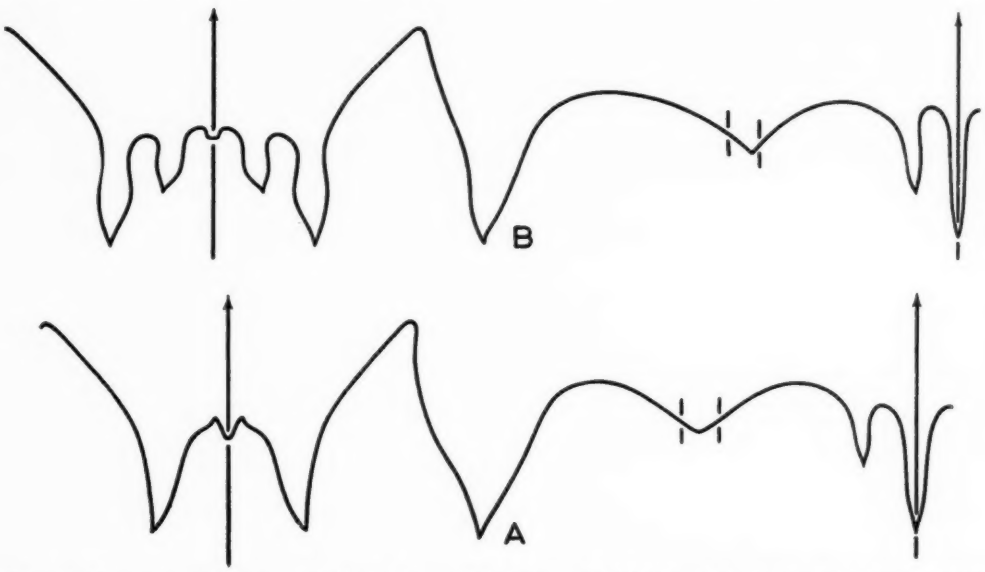


FIG. 3—Diagrammatic representations of complete sutures of **(A)** *Goniloboceras goniolobum* (Meek) and **(B)** *Neodimorphoceras texanum* (Smith), both ×2. The former is based primarily on a specimen (S. U. I. 1054) from the Finis shale near Jacksboro, Texas, and it shows the shape of the suture where the conch is about 35 mm. high. The latter represents a suture where the conch is about 30 mm. high, and it is based on a specimen (S. U. I. 1053) from the same shale about 3½ miles south of Jacksboro.

As shown by text figure 3A, each mature suture consists of a large prominently bifid ventral lobe and on either side of it a V-shaped but slightly sigmoidal subangular first lateral saddle, a somewhat similar acuminate first lateral lobe, a small low broadly rounded second lateral saddle, a small depressed-V-shaped lobe centering on the umbilical wall, a low broadly rounded internal second lateral saddle, a small narrow V-shaped acuminate internal lateral lobe, and a narrow U-shaped internal first lateral saddle which extends to the deep narrow V-shaped acuminate dorsal lobe.

The nature of the extreme adapical portion of the conch and the structure of the siphuncle and the septal necks of specimens from the Finis shale were illustrated and described in detail by Miller and Unklesbay in 1943. Also, the early ontogenetic development of the sutures in this species was clarified by Elias in 1938. Inasmuch as both of these reports are readily available, it does not seem necessary or even desirable for us to duplicate them.

Remarks.—Almost every author who has studied *Goniloboceras* has expressed a different opinion in regard to the relationships between the several species that have been proposed as representatives of it. The last is by Elias (1938, pp. 91–100), who concluded that *Goniatites parrishi* Miller and Gurley of the Kansas City group of west-central Missouri, *Milleroceras minusculum* Miller and *Goniloboceras discoidale* Böse of the Upper Pennsylvanian of south-central New Mexico, and *G. gracellenae* Miller and Cline of the Nellie Bly formation of northeastern Oklahoma "are the young of *G. goniolobum* or *G. welleri*" and that those two species

"are so closely related that even their specific separation may be questioned." After comparing and contrasting several hundred specimens from various horizons and localities in the Pennsylvanian of New Mexico, Texas, Oklahoma, Kansas, and Missouri, we have come to very similar conclusions, and furthermore we do not think that even *G. goniolobum* (Meek) and *G. welleri* Smith can be differentiated. That is, we believe that the single specimen (now lost) from some unrecorded horizon and locality in New Mexico on which Meek based *G. goniolobum* was somewhat worn ventrolaterally and/or that the published drawings of it are not accurate in detail; and that the differences between it and the type specimens of the subsequently proposed species listed above are more apparent than real and are due largely to preservation, interpretation, and the ontogenetic stage of development represented. It should perhaps be noted that none of the hundreds of specimens of *Gonioloboceras* now known have sutures exactly like those shown by Meek.

A few other forms have also been referred to *Gonioloboceras*. *G. bridgeportense* Plummer and Scott of the Graford formation (Canyon) of north-central Texas is probably also to be suppressed as a synonym of *G. goniolobum*, but we have not made a critical study of its type specimens and are therefore uncertain in regard to their specific affinities. A direct comparison of the types of *G. eliasi* Miller and Owen of the Cherokee of west-central Missouri with many specimens from Middle and Upper Pennsylvanian horizons makes it clear that the Lower Pennsylvanian individuals are more primitive in that the lobes and saddles of their sutures are not as sharply pointed—nevertheless, *G. eliasi* and *G. goniolobum* are closely related. The three poorly preserved specimens from the Lower Pennsylvanian of south-central Oklahoma which Miller and Owen (1944, pp. 418, 428, pl. 67, figs. 1–3) doubtfully referred to *Gonioloboceras* leave much to be desired, and we doubt that all of them are congeneric with each other or with the genotype of *Gonioloboceras*. Furthermore, as stated above, the species from the Carboniferous of Middle Asia which Librovitch referred to this genus are probably not closely related to the forms under consideration; but those described by Delépine from the lower Westphalian of Morocco seem to be very similar to *G. eliasi*, but possibly they are a little more primitive.

In conclusion, we believe that (with the possible exception of the type specimens of *G. bridgeportense*) all of the representatives of *Goniolobocerαs* known from the Middle and Upper Pennsylvanian are conspecific and should be referred to *Goniolobocerαs goniolobum*, the genotype. The only other forms that are definitely known to be congeneric are the types of *G. eliasi*, a closely related but somewhat more primitive species of the Lower Pennsylvanian However, the two specimens that Delépine recently reported from the lower Westphalian of Morocco are probably also referable to this genus.

Occurrence.—This species is known to be of widespread occurrence in the southwestern and midwestern portions of the United States and to have a long stratigraphic range in our Middle and Upper Pennsylvanian series. It has been found in New Mexico, Texas, Oklahoma, Kansas, Missouri, and Illinois. Stratigraphically it ranges at least from the Westerville limestone of the Kansas City group to almost the top of the Pennsylvanian system (Dry shale just above the Dover limestone). Plummer and Moore (1922, pp. 83, 84, 220) and Plummer and Scott (1937, p. 17) indicated that the species may be represented in the Mineral Wells formation of north-central Texas; we have not studied any specimens from there, but Plummer and Scott's statement (1937, p. 327) suggests that it may be *Gonioglyphioceras* rather than *Goniolobocerαs* that is represented in the Mineral Wells.

In the Finis shale of north-central Texas, *Goniolobocerαs goniolobum* is perhaps the most abundant ammonoid species, and the collections that we are studying contain many representatives of it from that shale at the following localities, all in Jack County: (1) about 6½ miles northeast of Jacksboro on the north side of the Jacksboro-Bridgeport road; (2) on the Ramzy and Riley ranches about 3½ miles east of Jacksboro, where specimens are abundant; and (3) in a cut along the Rock Island Railroad just east of the viaduct on the Mineral

Wells-Jacksboro highway about 3½ miles southeast of Jacksboro.

Repositories.—State University of Iowa, 1054 (text fig. 3A), 13809 (pl. 32, figs. 5, 6); and private collections of Robert J. Stark of Grapevine, Texas (pl. 31, fig. 9) and James P. Conlin of Ft. Worth, 3663 (pl. 32, fig. 9), 3681 (pl. 32, figs. 7, 8). Many additional specimens from the Finis shale are present in these collections, in those at The University of Texas, and in the private collections of Ralph H. King of Wichita Falls (Texas), and Merrill A. Stainbrook of Brandon (Iowa). The great majority of the numerous specimens at the State University of Iowa were collected by L. M. Cline, John Britts Owen, the J. H. Renfros, R. C. Spivey, Robert J. Stark and son, and the writers.

Genus NEODIMORPHOCERAS Schmidt, 1925

Genotype.—Dimorphoceras texanum Smith.

Although this genus is more or less gradational with *Dimorphoceras* Hyatt, 1884, both should be recognized. The type species of the latter, *Goniatites gilbertsoni* Phillips of the Viséan of England and Belgium, has a rounded rather than a grooved ventral zone, and at least its external sutures are relatively primitive in that the subdivisions of the ventral lobe are less nearly distinct and the first lateral saddles and lobes are rounded rather than pointed and are not sigmoidal. In the genotype and only known representative of *Shuichengoceras* Yin, 1935, *Goniloboceras* (S.) *yohi* Yin of the Lower Permian? of central China, the conch is narrowly rounded but not grooved ventrally, the "prongs" of the ventral lobe of the sutures are asymmetrically bifid and the first lateral saddles and lateral lobes of the external sutures are pointed—this genus can therefore be said to combine some of the characters of *Dimorphoceras* with some of those of *Neodimorphoceras*, but to be distinct from both. In 1927 Smith recognized that his species *Dimorphoceras texanum* is not very similar to typical *Dimorphoceras*, and he proposed the generic name *Texites* for it; but "while his paper was in press he was anticipated by Schmidt" (Smith, 1932, p. 23), who established the name *Neodimorphoceras* for the same species.

Insofar as we have been able to ascertain, only the following species have been referred to *Neodimorphoceras: Dimorphoceras texanum* Smith and *N. plummerae* Plummer and Scott of the Upper Pennsylvanian Graham formation of north-central Texas, *D. lenticulare* Girty and *D. oklahomae* Girty of the Middle Pennsylvanian Wewoka formation of central Oklahoma, *N. hawkinsi* Moore of the Bowland shale (Middle Carboniferous) of England, *N.* sp. of Schindewolf (1934, pp. 166–167, pl. 6, fig. 4) of the Namurian (Middle Carboniferous) of Menorca, and *N.* aff. *N. lenticulare* Ruzhencev (1936, p. 484) of the upper Uralian (late Upper Carboniferous) of the southern Urals. The Russian form does not seem to have been illustrated or described, but at least all of the others appear to be similar enough to the genotype to be regarded as congeneric with it, and we do not think that *N. plummerae* is even specifically distinct. In fragmentary specimens of *N. hawkinsi* that are available to us, the first lateral saddles of the external sutures are narrowly rounded, as in *Dimorphoceras*, but Moore (1930, p. 168, text fig. 1) indicated that in the holotype those saddles are pointed, as are the first lateral lobes and the subdivisions of the ventral lobe.

NEODIMORPHOCERAS TEXANUM (Smith)

Plate 32, figures 10, 11; plate 33, figures 1–13

Dimorphoceras texanum SMITH, 1903, U. S. Geol. Survey Mon. 42, pp. 16, 126–127, 138, 146, pl. 20, figs. 12–15; GIRTY, 1915, U. S. Geol. Survey Bull. 544, pp. 260, 261; PLUMMER and MOORE, 1922, Texas Univ. Bull. 2132, pp. 84, 145, 146, 150, pl. 25, fig. 6; WILLIAMS, 1938, Texas Univ. Publ. 3801, pp. 169, 170, 185, 188, 191, 225.

Neodimorphoceras texanum SCHMIDT, 1925, Preuss. geol. Landesanst. Jahrb. f. 1924, Bd. 45, pp. 512, 600; ——, 1929, Tierische Leitfossilien des Karbon, Gürichs Leitfossilien, Lief, 6, pp. 74–75, 105, pl. 20, figs. 1–3; SMITH, 1929, Am. Jour. Sci., 5th ser., vol. 17, p. 67; ——, 1932, U. S. Geol. Survey Prof. Paper 167, p. 23, pl. 43, figs. 4–7; SCHINDEWOLF, 1934, Göttingen Gesell. Wissensch., Abh., math.-physik. Kl., Folge 3, Heft 10, pp. 164, 166, 167; PLUMMER, 1937, Am. Jour. Sci., 5th ser., vol. 33, p. 465; —— and SCOTT, 1937, Texas Univ. Bull. 3701, pp. 18, 30, 33, 332, 341, 342–343, 344, 345, 346, 347, 399, text fig. 88 (opp. p. 402), pl. 35, figs. 5–8; MILLER and UNKLESBAY, 1943, Jour. Paleontology, vol. 17, p. 19, text fig. 9E; SHIMER and SHROCK,

1944, Index fossils of North America, p. 575, pl. 236, figs. 5, 6.

Texites texanus, SMITH, 1927, U. S. Geol. Survey Prof. Paper 141, pl. 20, figs. 4–7.

Neodimorphoceras plummerae, PLUMMER and SCOTT, 1937, Texas Univ. Bull. 3701, pp. 342, 343–345, text fig. 88 (opp. p. 402), pl. 35, figs. 1–4.

The general physiognomy of the conch of this species is shown by the accompanying illustrations. The phragmacone, which is relatively narrower at maturity than during adolescence, attains a maximum diameter of at least 75 mm. and a corresponding height and width of conch of about 42 mm. and 23 mm., respectively. None of the numerous phragmacones in the collections we are studying retains even a portion of the living chamber, but fragments of that chamber indicate that it was large and probably long.

The umbilicus, though never perforate, is open during adolescence (pl. 33, figs. 10, 11), but at full maturity it is small, inconspicuous, and most probably closed (pl. 32, fig. 11).

The growth lines form ventral and lateral sinuses and dorsolateral and prominent ventrolateral salients. The sinuosity becomes progressively greater throughout ontogenetic development, and also relatively finer and more numerous. On well preserved early mature testiferous specimens, like that illustrated by figures 3 and 4 on plate 33, fine longitudinal lines can also be discerned on the surface of the test. These are particularly evident along a narrow ventral zone which very gradually becomes flattened and then develops into a groove which can be recognized in some conchs 15 mm. or less high and which was retained throughout ontogenetic development. This groove is present on both the exterior of the test and the internal mold, but its development and/or preservation seem to have been somewhat variable, for we have two internal molds in which the conch attains a height of about 30 mm. before it can be discerned.

Some small limonitic internal molds, from a shale a little younger than the Finis but nevertheless part of the same formation, that is, the Wayland shale, clearly show the early growth stages of the conch (pl. 33, figs. 8–13). These indicate that at a diameter of some 3 mm. each external suture (text fig. 4A) consists of a large subdivided ventral lobe and on either side of it two rounded saddles and one rounded lobe. In the next suture (text fig. 4B; pl. 33, fig. 9) slight salients are developed on the ventral side of both of the major subdivisions of the ventral lobe. In the following suture (text fig. 4C; pl. 33, fig. 9), these become much more prominent. Slightly larger specimens (text fig. 4D; pl. 33, figs. 11–13 and 1, 2) show that these salients gradually develop into prominent subdivisions of the ventral lobe and that meanwhile the first lateral saddles and the first lateral lobes of the external sutures become pointed. The shape of both the external and the internal sutures of a large fully mature individual is portrayed by text figure 3B.

Remarks.—The many specimens available to us make it clear that the minute differences on which Plummer and Scott relied to distinguish *N. texanum* and their species *N. plummerae* are more apparent than real and are due to preservation, interpretation, and ontogenetic stage represented. *N. lenticulare* Girty and *N. oklahomae* Girty of the Wewoka formation of Oklahoma have a narrowly rounded rather than a grooved ventral zone and possibly their sutures may be a little less advanced. Nevertheless, all three of these species are closely similar. We have not seen the Wewoka specimens which Morgan (1924, p. 100, pl. 51, fig. 6) referred to "*Dimorphoceras*" *texanum*, but at least the figured one probably belongs in *N. oklahomae*, a species which according to Morgan (1924, p. 118) occurs in the Francis as well as the Wewoka formation. It should, however, be noted that Smith (1929, p. 67) listed *N. texanum* with question from the Wewoka.

Occurrence.—This species is definitely known from only the Graham formation of north-central Texas, where it is fairly abundant in two members, the Finis shale and the somewhat younger Wayland shale. We have specimens from the Finis at the following localities, all in Jack County, Texas: (1) about 6½ miles northeast of Jacksboro on the north side of the Jacksboro-Bridgeport road; (2) on the Ramzy and Riley ranches about 3½ miles east of Jacksboro, where specimens are fairly abundant; and (3) in a cut along the Rock Island Railroad just east of the viaduct on

the Mineral Wells-Jacksboro highway about 3½ miles southeast of Jacksboro.

Repositories.—State University of Iowa, 1053 (text fig. 3B), 13828 (pl. 33, figs. 8–13), 13829 (pl. 32, figs. 10, 11); and private collection of James P. Conlin of Ft. Worth, 3537 (pl. 33, figs. 5–7), 3547 (pl. 33, figs. 3, 4), 3549 (pl. 33, figs. 1, 2). Many additional specimens from the Finis shale are present in both of these collections, in those at the University of Texas, and in the private collections of Ralph H. King of Wichita Falls, Texas, and Merrill A. Stainbrook of Brandon, Iowa.

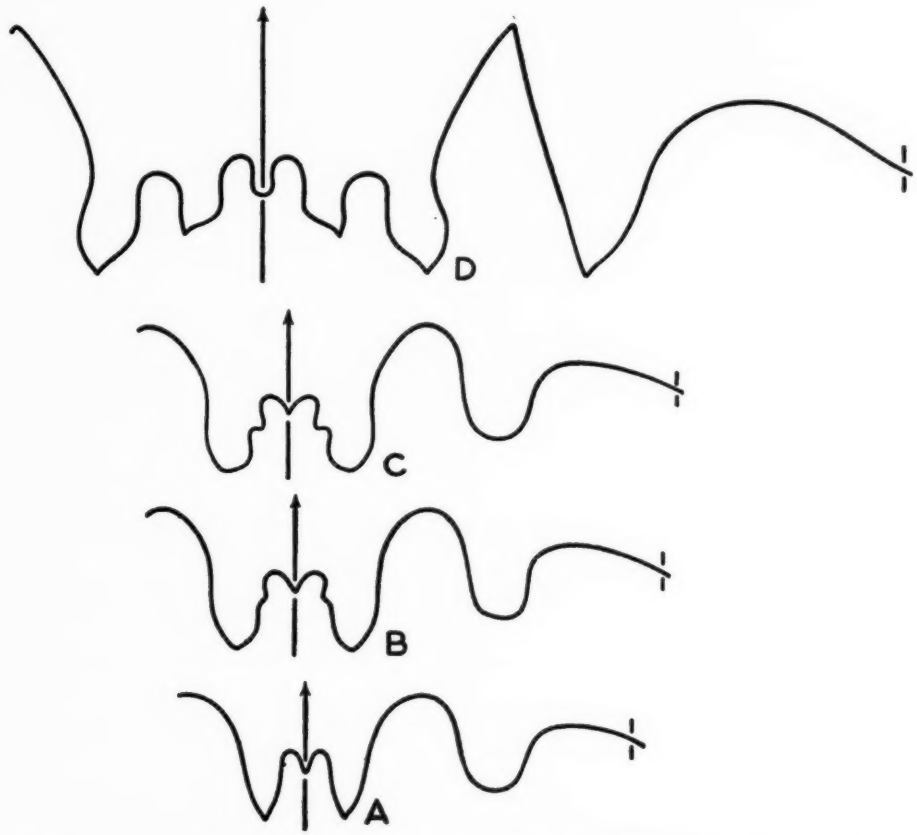


FIG. 4—Diagrammatic representations of external sutures of *Neodimorphoceras texanum* (Smith) during ontogenetic development. **A–C** portray the three successive sutures immediately apicad of the septum which forms the adoral margin of the specimen illustrated by figures 8–10 on plate 33, all ×25. **D** is based on a suture near the mid-length of the adoral half-volution of the specimen illustrated by figures 1, 2 on the same plate, ×8½.

Genus EOASIANITES Ruzhencev, 1933

Genotype.—Eoasianites subhanieli Ruzhencev.

Miller and Furnish (1940, pp. 77–78) have summarized the available data in regard to this genus, and we are not able to add significantly to their discussion. Three species occur in the Finis shale, where two are abundant and the other is not rare. All three are illustrated on plate 31 and are discussed in the following paragraphs. Representatives of this genus are both abundant and widespread in the Pennsylvanian strata. They show so much individual

variation that it is difficult to delimit species precisely, and these are therefore customarily allowed considerable latitude, as a matter of expediency.

EOASIANITES ANGULOUMBILICATUS
(Plummer and Scott)
Plate 31, figures 7, 8

? *Gastrioceras* sp. SCOTT and ARMSTRONG, 1932, Texas Univ. Bull. 3224, p. 39.
Glaphyrites anguloumbilicatus PLUMMER and SCOTT, 1937, Texas Univ. Bull. 3701, pp. 17, 33, 264, 271–273, 278, text fig. 88 (opp. p. 402), pl. 15, fig. 9, pl. 17, figs. 14–20.

By far the most abundant representative of *Eoasianites* in the Finis shale is a form that seems to come well within the limits of *E. anguloumbilicatus*, as defined by Plummer and Scott. The specimen that we are illustrating is essentially complete, but otherwise it is typical of those in the collections we are studying. It is about 29 mm. in diameter, but some specimens show that the conch attained a diameter of at least 45 mm. The living chamber was almost a full volution (or more) in length. The diameter of the umbilicus is equal to only a little less than a third of that of the specimen. The umbilical shoulders are subangular, and the umbilical walls, though very slightly convex, are steep.

The test is thin and its surface bears numerous fine transverse growth lines, which form a very slight ventral sinus and on either side of it similar but narrower lateral salients. The internal mold and probably to a less extent the surface of the test is marked by transverse constrictions which are parallel to the growth lines; these are not particularly prominent and become obsolete during late ontogenetic development. Text figure 5A shows the shape of the external sutures.

Remarks.—The umbilicus of this form

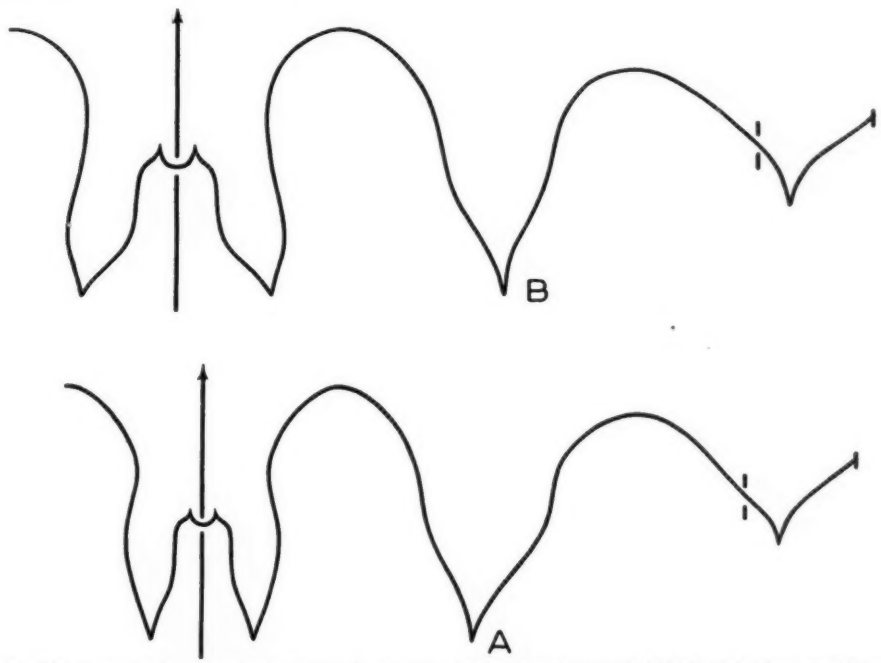


FIG. 5—Diagrammatic representations of mature external sutures of **(A)** *Eoasianites anguloumbilicatus* (Plummer and Scott) and **(B)** *E. modestus* (Böse) ×8¾ and ×4¼, respectively. The first is based on the adoral suture of the specimen represented by figures 7, 8 on plate 31, where the conch is some 15 mm. in diameter; and the last portrays the adoral suture of the specimen represented by figures 13, 14 on the same plate, at a diameter of about 34 mm.

serves to differentiate it readily from the two congeneric species which occur in direct association with it in the Finis shale.

Occurrence.—In the Finis shale this species is known to occur at the following localities, all in Jack County: (1) 4 miles east-northeast of Jacksboro (figured specimen), (2) Ramzy and Riley ranches about 3½ miles east of the same town (24 specimens), and (3) the Rock Island Railroad cut about 3½ miles southeast of Jacksboro (4 specimens). This species is also abundant in the Graford formation of the Canyon group in north-central Texas, which yielded the syntypes.

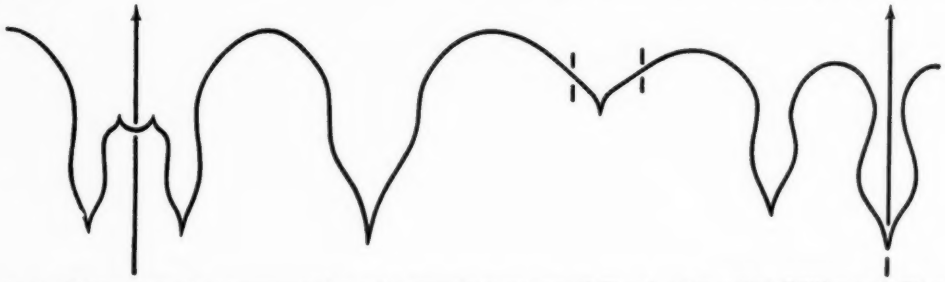


FIG. 6—Diagrammatic representation of a complete suture of *Eoasianites millsi* (Miller and Cline)? ×5¼. This drawing is a composite figure with calculated proportions, and it illustrates the shape of the sutures where the conch is about 23 mm. in diameter.

Repositories.—State University of Iowa, 1057, 1070 (figured specimen), 13798; and the private collections of James P. Conlin of Ft. Worth (Texas), Ralph H. King of Wichita Falls (Texas), Robert J. Stark of Grapevine (Texas), and Merrill A. Stainbrook of Brandon (Iowa).

EOASIANITES MILLSI Miller and Cline?
Plate 31, figures 10–12

? *Gastrioceras* sp. B. PLUMMER and MOORE, 1922, Texas Univ. Bull. 2132, p. 145; SCOTT and ARMSTRONG, 1932, Texas Univ. Bull. 3224, p. 39.

? *Gastrioceras millsi* MILLER and CLINE, 1934, Jour. Paleontology, vol. 8, pp. 177–178, pl. 28, figs. 7–9.

? *Glaphyrites millsi* PLUMMER and SCOTT, 1937, Texas Univ. Bull. 3701, pp. 33, 264, 273–274, 276, 387, text fig. 88 (opp. p. 402), pl. 16, figs. 10–13.

? *Gastrioceras angulatum* WILLIAMS, 1938, Texas Univ. Publ. 3801, pp. 185, 225.

James P. Conlin of Fort Worth loaned us seven specimens from the Finis shale that resemble the holotype of *E. millsi* in general physiognomy but are much larger and have sutures in which the lobes are more attenuate. The best of these is figured. It is completely septate and therefore represents only phragmacone. Its maximum diameter measures about 26 mm., and near its adoral end its conch is about 10 mm. high and is estimated to have had a corresponding width of some 25 mm. The umbilicus is large and open and that of the figured specimen has a maximum diameter of about 16 mm. The surface of the internal mold bears moderately prominent transverse constrictions which form broad rounded salients as they cross the external or ventral portion of the conch. On the adapical portion of the outer volution of the specimen we are illustrating, there is a trace of reticulate ornamentation, which may represent the "runzelschicht." The shape of both the internal and the external sutures is shown by text figure 6.

Remarks.—We are uncertain as to the relationship of the specimens under consideration with the holotype of *E. millsi*. That individual is only about 5½ mm. in diameter, but all except possibly its extreme adoral portion is septate. Furthermore, its general physiognomy and particularly the fact that its camerae are long suggest that it represents only the immature portion of a conch. All in all, its similarities to Finis shale specimens seem to us to be more significant than its differences. Therefore we are tentatively regarding our specimens as conspecific with it, but in order to call attention to our uncertainty we are using an interrogation point. *E. angulatus* (Girty) of the Wewoka formation of Oklahoma and possibly the Canyon group of north-central

Texas is similar, but the relative size of the lobes in its external sutures is considerably different.

Occurrence.—Finis shale on Riley ranch about 3½ miles east of Jacksboro, Jack County, Texas. The holotype came from the Nellie Bly formation about 6½ miles due west of Sand Springs, Tulsa County, Oklahoma. Plummer and Scott indicated that specimens which they regarded as "typical" of Miller and Cline's species occur in the Wayland shale at several localities in north-central Texas.

Repositories.—Private collection of James P. Conlin of Ft. Worth (all seven of the specimens from the Finis shale). The holotype is at the State University of Iowa, where its catalogue number is 635. The specimens studied by Plummer and Scott are at The University of Texas.

EOASIANITES MODESTUS (Böse)
Plate 31, figures 13, 14

Gastrioceras modestum BÖSE, 1919, Texas Univ. Bull. 1762, pp. 17, 36, 37, 83–85, pl. 2, figs. 4–27; SMITH, 1929, Am. Jour. Sci., 5th ser., vol. 17, p. 67; WILLIAMS, 1938, Texas Univ. Publ. 3801, pp. 188, 191, 225.

? Gastrioceras subcavum SMITH, 1929, Am. Jour. Sci., 5th ser., vol. 17, p. 67.

? Gastrioceras sp. SCOTT and ARMSTRONG, 1932, Texas Univ. Bull. 3224, p. 39.

Glaphyrites modestus RUZHENCEV, 1936, Prob. Soviet Geol., tom 6, no. 12, pp. 1081, 1082, 1087.

Glaphyrites kansasensis [part] PLUMMER and SCOTT, 1937, Texas Univ. Bull. 3701, pp. 17, 22, 30, 32, 33, 264, 266, 267, 274–276, 278, 283, 285, 387, 388, 389, 390, text fig. 88 (opp. p. 402), pl. 17, figs. 1–13.

Paragastrioceras deciense [part] PLUMMER and SCOTT, 1937, Texas Univ. Bull. 3701, only p. 226 [not pl. 24, fig. 16].

? Preshumardites gaptankensis [part] PLUMMER and SCOTT, 1937, Texas Univ. Bull. 3701, pp. 22, 34, 288, 289, 291–292, text fig. 88 (opp. p. 402), pl. 24, fig. 6 [not 4, 5].

Eoasianites modestus MILLER and FURNISH, 1940, Geol. Soc. America Spec. Paper 26, pp. 13, 15, 20, 78, 79, 80–81, pl. 12, figs. 5–9 [probably not 4]; pl. 13, fig. 7.

The Finis shale carries a good many representatives of *Eoasianites* that seem to be referable to *E. modestus*, as redefined by Miller and Furnish in 1940. The specimen we are figuring is a little larger than the average of those in the collections under consideration. Its maximum diameter measures about 35 mm., near its adoral end its conch is about 14 mm. high and 24 mm. wide, and its umbilicus attains a diameter of about 14 mm. Fragments from the same horizon and locality indicate that the phragmacone attained dimensions at least 25 per cent greater than those of the figured individual.

At least the internal mold in this species bears transverse constrictions which form low broadly rounded ventral salients. Also, well preserved specimens bear traces of the increments of growth, and they are parallel to the constrictions. The shape of the external sutures is shown by text figure 5B. As in other representatives of this genus, the internal sutures consist of three lobes and four saddles, but the precise shape of these inflections was not ascertained although the internal saddles are all rounded.

Remarks.—We are referring to this species 11 specimens from the Finis shale. They show a certain amount of variation particularly with respect to the relative height and width of the conch and the diameter of the umbilicus, but such variability seems to be the rule in species of this genus.

As has been noted previously by other authors, *E. kansasensis* (Miller and Gurley) and *E. gaptankensis* (Miller) resemble this species in general physiognomy, and all may be conspecific. However, in both of those forms the ventral lobe of the sutures seems to be relative large, the taxonomic significance of which is questionable. Furthermore, the private collection of R. J. Stark contains one small immature specimen from the Finis in which the ventral lobe of the sutures is large.

Occurrence.—As now interpreted, this species is of rather widespread occurrence in the Upper Pennsylvanian and Lower Permian of north-central and west Texas. All of the specimens that we have from the Finis shale came from the Ramzy and Riley ranches about 3½ miles east of Jacksboro, Jack County, Texas.

Repositories.—State University of Iowa, 1058; and private collections of James P. Conlin of Ft. Worth (3707—figured specimen), R. J. Stark of Grapevine (Texas), and Merrill A. Stainbrook of Brandon (Iowa).

Genus SCHISTOCERAS Hyatt, 1884

Genotype.—Goniatites missouriensis Miller and Faber.

Miller and Furnish (1940, pp. 537–539) have published a detailed analysis of this genus based on a study of numerous specimens from many horizons and localities in the Middle and Upper portions of our Pennsylvanian system. They showed that, contrary to the prevailing beliefs at the time, all of the representatives of the genus known from America are referable to only two species, *S. hildrethi* (Morton) and *S. missouriense* (Miller and Faber). There is even gradation between these two, but the extremes within the group are believed to be worthy of specific recognition. *S. hildrethi* is characterized by a large umbilicus, nodose umbilical shoulders during early maturity, and relatively prominent reticulate ornamentation; whereas in *S. missouriense* the umbilicus is relatively small, during early maturity the umbilical shoulders are smooth (or nearly so), and the ornamentation of the test is relatively fine and inconspicuous. All of the representatives of this genus that have been described and/or illustrated came from the Pennsylvanian (and possibly the Lower Permian) of the United States, but Ruzhencev (1945, p. 289) has listed the genus as occurring in the Orenburgian of the southern Urals.

SCHISTOCERAS HILDRETHI (Morton)
Plate 35, figure 3

This species as defined and synonymized by Miller and Furnish (1940, pp. 539–540) is rare in the Finis shale, and the collections that we are studying contain only fragments of it. The one that we are illustrating has a moderately large umbilicus and prominently nodose umbilical shoulders, except in its extreme adoral portion. Fragments, representing only a few camerae, show that in some individuals the whorls are relatively low and broad and the umbilicus is larger. As might be expected, a study of this rather inconsequential material has not enabled us to add to the existing knowledge of the species.

Prehoffmannia milleri Plummer and Scott was based on a single "minute . . . discoidal, compressed, widely umbilicate, strongly ribbed, non-septate" specimen, which may be an immature representative of this species. It came from the "base of the Graham formation 1½ miles east of Caddo, Stephens County," Texas.

Occurrence.—We have only four specimens that we are referring to this species, and all of them came from about 3½ miles east of Jacksboro, Jack County, Texas. However, the species is known to be of widespread occurrence in the upper half of the Pennsylvanian system and to be represented in Pennsylvania, Ohio, Illinois, Missouri, Kansas, Oklahoma, and both north-central and west Texas. In north-central Texas it ranges stratigraphically from the upper part of the Strawn well up into the Cisco (upper Graham).

Repository.—Private Collection of James P. Conlin of Ft. Worth, 3654 (illustrated specimen), 3655–3657.

SCHISTOCERAS MISSOURIENSE (Miller and Faber)
Plate 34, figures 7–9

Although the collections under consideration contain more than 100 representatives of this species from the Finis shale, we are unable to add significantly to the diagnosis and the synonymy that was published by Miller and Furnish (1940, pp. 540–541). With the exception of *Goniolobocerας goniolobum* (Meek), *S. missouriense* is the most abundant ammonoid in the Finis. Furthermore representatives of it are large and therefore conspicuous, and some of them show that the phragmacone attained a diameter of at least 88 mm. Testiferous individuals bear relatively fine reticulate ornamentation, and when slightly worn retain only the longitudinal lirae.

Occurrence.—Altogether we have representatives of this species from the Finis shale at the following localities, all in Jack County, Texas: (1) about 4 miles east-northeast of Jacksboro (2 specimens), (2) the Ramzy and Riley ranches some 3½ miles east of the same town (99 specimens), and (3) the Rock Island Railroad cut about 3½ miles southeast of Jacksboro (5 specimens). Furthermore, the species is known to be of widespread occurrence in the upper half of our Pennsylvanian system and to be represented in Pennsylvania, Ohio, Illi-

nois, Missouri, Kansas, Oklahoma, and both north-central and west Texas. In north-central Texas it has been found to range stratigraphically from the upper part of the Canyon to well up into the Cisco (upper Graham) and possibly into the Lower Permian (Belle Plaine).

Repositories.—State University of Iowa, 1059 (pl. 34, figs. 7, 8), 1060; and private collections of James P. Conlin of Ft. Worth (Texas) [pl. 34, fig. 9; and a great many unfigured specimens], Ralph H. King of Wichita Falls (Texas) and Merrill A. Stainbrook of Brandon (Iowa).

Genus EOTHALASSOCERAS Miller and Furnish, 1940

Genotype.—Prothalassoceras inexpectans Miller and Owen.

Since this genus was established additional data in regard to it have become available. As explained in the discussion of *E. caddoense* (Plummer and Scott), we are placing in that species all of the representatives of the genus known from north-central Texas, and we believe that they are specifically distinct from the congeneric forms that have been described from west Texas.

The numerous specimens from various horizons and localities that are now available to us indicate that, at least as far as internal molds are concerned, the presence or absence of longitudinal ventrolateral grooves (like the smaller details of the denticulations of the lobes of the external sutures) is largely a matter of preservation. Therefore, contrary to the opinion expressed by Miller and Furnish, this feature can probably not be used to distinguish the two forms from the upper part of the Gaptank formation of west Texas for which names have been proposed, *E. keytei* (Smith) and *E. kingorum* (Miller), and it is very doubtful if both of these should be retained—the former has priority. *E. inexpectans* (Miller and Owen) of the Middle Pennsylvanian of Oklahoma is a third valid species of this genus. Therefore, all of the known American representatives of this genus are probably referable to three species. One of these is characteristic of the Middle Pennsylvanian of Oklahoma, another of the Upper Pennsylvanian of north-central Texas, and the third of the Upper Pennsylvanian of west Texas.

Aristoceras chakalovi Ruzhencev of the Upper Carboniferous of the Ural region is very close to *E. caddoense.* It is the genotype of *Aristoceras* Ruzhencev, and as that generic name was established later in the same year as *Eothalassoceras* it should be suppressed as a synonym. According to Ruzhencev (1940, p. 524), *Uralites* Voinova, 1934 [not Tchernow, 1907], *nomen nudum*, is also synonymous.

In summary, *Eothalassoceras* is now known to occur in the Middle Pennsylvanian of Oklahoma, the Upper Pennsylvanian of north-central and west Texas, and the Upper Carboniferous (Orenburgian) of the Ural region.

EOTHALASSOCERAS CADDOENSE (Plummer and Scott)

Plate 34, figures 5, 6; plate 35, figure 6

Prothalassoceras texana [*nomen nudum*] SCOTT and PLUMMER, 1930, Geol. Soc. America, Bull., vol. 41, p. 104.

Prothalassoceras sp. MILLER, Jour. Paleontology, vol. 4, p. 408.

Prothalassoceras kingorum PLUMMER, 1937, Am. Jour. Sci., 5th ser., vol. 33, p. 465; [part] —— and SCOTT, 1937, Texas Univ. Bull. 3701, pp. 18, 353–354, 399, text fig. 88 (opp. p. 402), pl. 36, figs. 7–15 [not 16].

Prothalassoceras caddoense PLUMMER and SCOTT, 1937, Texas Univ. Bull. 3701, pp. 18, 353, 355–356, text fig. 88 (opp. p. 402), pl. 36, figs. 4–6.

Eothalassoceras kingorum MILLER and FURNISH, 1940, Geol. Soc. America Special Paper 26, p. 105.

Eothalassoceras caddoense MILLER and FURNISH, 1940, Geol. Soc. America Special Paper 26, p. 105.

Aristoceras? caddoense RUZHENCEV, 1940, URSS Acad. Sci., C. R. (Doklady), vol. 27, no. 5, p. 526.

Conch moderate in size and subdiscoidal in shape, attaining a maximum diameter of at least 40 mm. and a corresponding height and width of about 23 mm. and 15 mm., respectively. Whorls are strongly flattened laterally, rather narrowly rounded ventrally, and impressed dorsally—their maximum width is attained just outside the umbilical shoulders. Living chamber is almost a volution (or more) in length.

Umbilicus small, inconspicuous, and closed. Umbilical shoulders rounded and indefinite

Surface of test bears fine growth lines which are strongly sinuous and form rather

deep rounded ventral and lateral sinuses, similar but smaller and lower dorsolateral salients, and more prominent and almost subangular ventrolateral salients. Also, in at least well preserved internal molds there is a distinct rounded longitudinal groove on each ventrolateral zone (see pl. 35, fig. 6).

As shown by text figure 7, each external suture forms a large bifid ventral lobe with digitate prongs, and on either side of it a U-shaped first lateral saddle, a digitate first lateral lobe, and a moderately deep rounded second lateral saddle, which extends to a small lobe on the umbilical seam. The details of the digitation of the lobes of the external sutures are not the same on the two sides of the figured specimen.

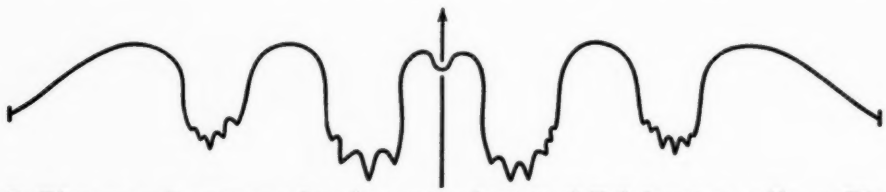


FIG. 7—Diagrammatic representation of an external suture of *Eothalassoceras caddoense* (Plummer and Scott), based on the specimen represented by figures 5, 6 on plate 34 at a diameter of about 17 mm., ×5¼.

Remarks.—Plummer and Scott based this species on small specimens from the Wayland shale of north-central Texas, and they referred some larger individuals from that shale and from the slightly older Finis shale of the same general locality to *E. kingorum* (Miller) [=? *E. keytei* (Smith)], the types of which came from the upper part of the Gaptank formation of west Texas. Miller and Furnish expressed the opinion that all of these are probably conspecific. A direct comparison of specimens from the two shales in north-central Texas has convinced us that only one species is represented there, but these specimens appear to have relatively narrower conchs than do those from west Texas, and presumably therefore are specifically distinct. *E. inexpectans* (Miller and Owen) of the Middle Pennsylvanian of Oklahoma also has a relatively wide conch in comparison to *E. caddoense*, and it does not seem to be particularly closely related to that species or to *E. keytei*.

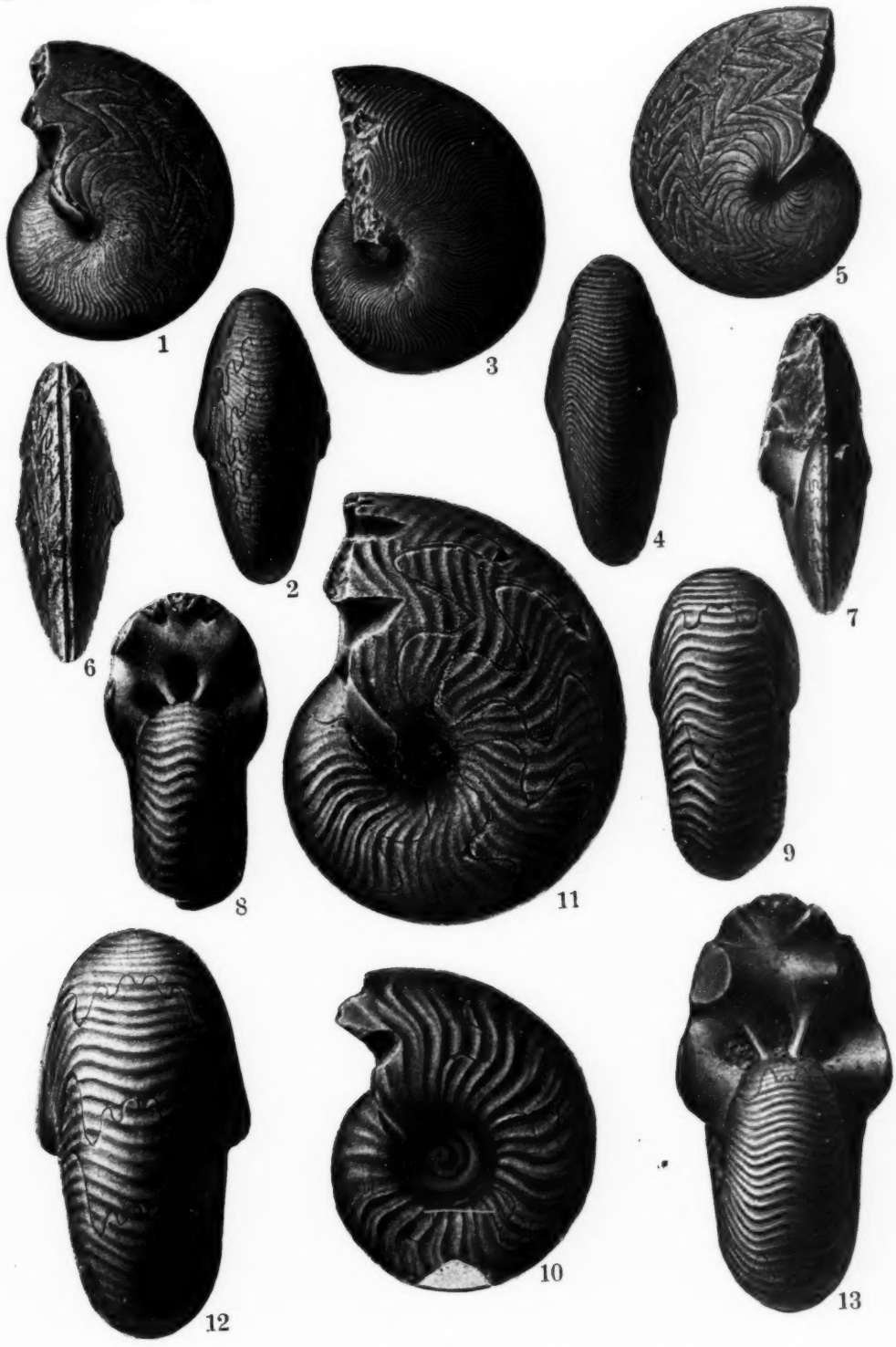
The private collection of James P. Conlin of Ft. Worth contains a somewhat crushed but otherwise moderately well preserved phragmacone (no. 3201) which appears to be referable to this species and which is about 33½ mm. in diameter. This specimen is remarkable for its large size and for the fact that it came from a locality and horizon where the genus was previously unknown, the "shale above the Willow Point limestone," that is, the Lake Bridgeport shale (about middle Canyon) in the claypit at Bridgeport, Wise County, Texas.

Aristoceras chkalovi Ruzhencev of the Orenburgian of the Urals seems to be strikingly similar to *E. caddoense*, and the two are certainly congeneric. The published figures of the type specimens of that Russian species show a double ventrolateral groove, but some of the small specimens in our collections from the Wayland shale of north-central Texas also are similarly marked, and therefore we are of the opinion that little taxonomic significance should be attributed to this feature.

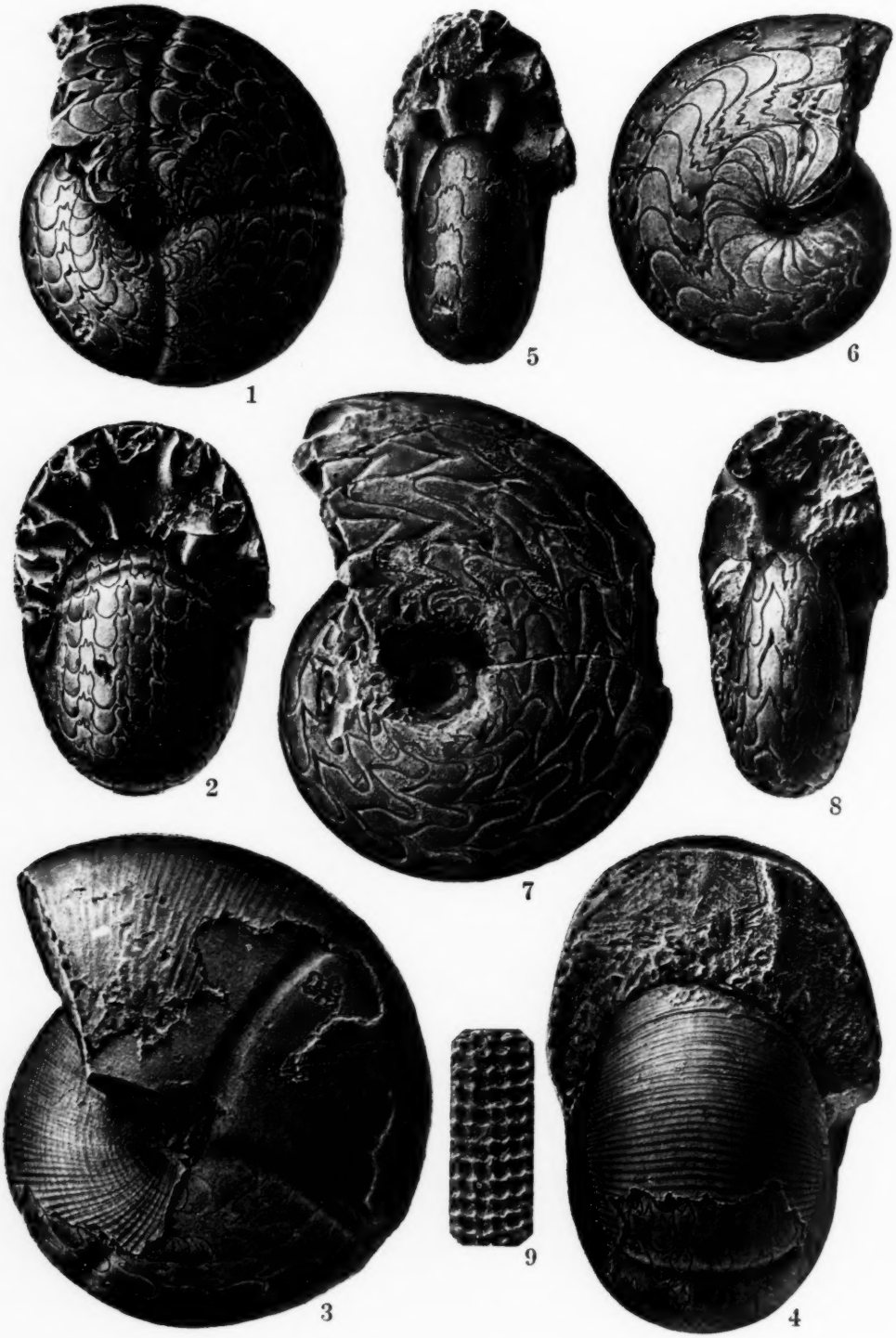
Occurrence.—As interpreted by us, this species occurs in the Lake Bridgeport, Finis, and Wayland shales of north-central Texas. From the Finis we have representatives of it at the following two localities,

EXPLANATION OF PLATE 33

FIGS. *1–13*—*Neodimorphoceras texanum* (Smith). Five specimens showing the surface ornamentation and the sutures at various stages of growth. *1–7*, From the Finis shale about 3 miles due east of Jacksboro, Texas. *1, 2*, (J. P. C. 35 9); *3, 4*, (J.P.C. 3547); *5–7*, (J.P.C. 3537). *8–13*, from the Wayland shale, slightly higher in the Graham formation, about 5 miles north of the same town (S.U.I. 13828). *1–4*, ×3; *5–7*, ×1; *8–13*, ×10. (p. 200)



Miller and Downs, Pennsylvanian ammonoids



Miller and Downs, Pennsylvanian ammonoids

both in Jack County: (1) the Ramzy and Riley ranches about 3½ miles east of Jacksboro, and (2) about 4 miles south of the same town. Also, Plummer and Scott have figured a specimen, which is almost certainly conspecific, from the Finis shale in the Rock Island Railroad cut about 3½ miles southeast of Jacksboro.

Repositories.—State University of Iowa, 13835; and private collections of James P. Conlin of Ft. Worth (Texas) [pl. 35, fig. 6, and five unfigured specimens], Robert J. Stark of Grapevine (Texas) [pl. 34, figs. 5, 6], and Ralph H. King of Wichita Falls (Texas) [1 unfigured specimen].

Genus AGATHICERAS Gemmellaro, 1888

Genotype.—Agathiceras suessi Gemmellaro.

This well known genus is one of the most abundant ammonoids in the Late Paleozoic, insofar as number of individuals is concerned. Furthermore, it is of world-wide occurrence, and stratigraphically it ranges throughout almost all of the Pennsylvanian and all but the upper portion of the Permian. Nevertheless, it seems to be rare in the Finis shale, and the collections we are studying contain only one specimen that belongs in it.

Plummer and Scott (1937, pp. 18, 119–122, text fig. 88 [opp. p. 402]) indicated that from the same locality which yielded our specimen, they had one specimen of *A. frechi* Böse and one or more of *A. ciscoense* Smith. However, they stated (p. 120) that both of these "may prove from the study of more material to be identical," a conclusion with which we are inclined to agree. We believe that the characters by which they attempted to distinguish the two are probably due primarily to differences in ontogenetic stage represented and possibly also to preservation and interpretation. The types of Böse's species, which came from the Gaptank formation of west Texas, may however, be specifically distinct from those of Smith's, which came from the Wayland shale of north-central Texas.

AGATHICERAS CISCOENSE Smith
Plate 35, figures 11, 12

Agathiceras ciscoense SMITH 1903, U. S. Geol. Survey. Mon. 42, pp. 16, 131, 138, 146, pl. 21, figs. 17–19; ——, 1913, Zittel-Eastman Textbook of paleontology, vol. 1, 2d ed., p. 640, fig. 1212; HANIEL, 1915, Paläont. von Timor, Lief. 3, Abh. 6, pp. 67, 71; BÖSE, 1919, Texas Univ. Bull. 1762, pp. 113, 117, 120; PLUMMER and MOORE, 1922, Texas Univ. Bull. 2132, pp. 149, 220; SMITH, 1927, U. S. Geol. Survey. Prof. Paper 141, pl. 20, figs. 22–24; ——, 1927, Nederlandsch-Indië Jaarb. Mijnw., Jaarg. 55 (1926), Verh. 1, p. 40; ——, 1929, Am. Jour. Sci., 5th ser., vol. 17, p. 67; SCHINDEWOLF, 1931, Preuss. geol. Landesanst, Sitzungsber., Heft 6, p. 200; SMITH, 1932, U. S. Geol. Survey. Prof. Paper 167, p. 24, pl. 43, figs. 22–24; PLUMMER and SCOTT, 1937, Texas Univ. Bull. 3701, pp. 18, 30, 119, 121–122, text fig. 88 (opp. p. 402), pl. 28, figs. 8–16.

? Agathiceras frechi [part] PLUMMER and SCOTT Texas Univ. Bull. 3701, pp. 18, 119–121, 394, pl. 28, figs. 3, 5 [not 1, 2, 4, 6, 7].

The single specimen that we are referring to this species is well preserved, but the adoral portion of its outer volution is somewhat crushed. It is testiferous throughout and does not reveal the sutures.

The maximum over-all dimension of this specimen is about 38 mm. Near the adapical end of the outer volution, where the conch is free from distortion, it is about 11½ mm. high and 12½ mm. wide. The umbilicus is small and closed.

The surface of the test bears prominent longitudinal ribs which are about half as wide as the intermediate grooves. These

EXPLANATION OF PLATE 34

All specimens are from the Finis shale of north-central Texas.

FIGS. *1–4—Peritrochia ganti* (Smith). *1, 2*, Specimen from 4 miles south of Jacksboro (S.U.I. 1067); *3, 4*, specimen from 3 miles southeast of the same town (S.U.I. 1061). All ×3. (p. 210)

5, 6—Eothalassoceras caddoense (Plummer and Scott). Two views of a phragmacone (R. J. S.), from about 3½ miles east of Jacksboro, ×3. (p. 207)

7–9—Schistoceras missouriense (Miller and Gurley). *7*, Lateral view of a large phragmacone; *8*, ventral view of all but the adoral quarter-volution of the same specimen (S.U.I. 1059), ×1. *9*, An enlargement of the ventral portion of a testiferous specimen (J. P. C. 3653), ×6. Both specimens from about 3½ miles east of Jacksboro. (p. 206)

ribs are essentially straight-sided and flat-topped, and the grooves are flat-bottomed. Fine sinuous transverse growth lines are also present. They cross both the ribs and the grooves and form broad moderately shallow rounded ventral and lateral sinuses and ventrolateral and dorsolateral salients.

Remarks.—In all available particulars, the specimen under consideration seems to resemble Smith's holotype very closely. Furthermore, both are of about the same size.

Occurrence.—Finis shale in the Rock Island Railroad cut about 3½ miles southeast of Jacksboro, Jack County, Texas. The holotype of this species came from the Wayland shale in a high bluff on the west side of Salt Creek west of Graham, Young County, Texas; and the John Britts Owen collection at the State University of Iowa contains two moderately small limonitic internal molds from the Wayland about 5 miles north of Jacksboro, on the Antelope Road. Insofar as we have been able to ascertain the species is not known to occur at any other horizon or localitity.

Repository.—State University of Iowa, 13764.

Genus PERITROCHIA Girty, 1908

Genotype.—Peritrochia erebus Girty.

Although this genus was long neglected, Miller and Furnish (1940, pp. 121–127, 179) restudied the original specimens on which it was based and showed that they are similar enough to the genotypes of the subsequently described *Marathonites* Böse, 1919, and *Prostacheoceras* and *Kargalites*, both of Ruzhencev, 1938, to be regarded as congeneric with them. It is gradational with *Stacheoceras* Gemmellaro, 1887, and differs from that genus only in the simplicity of its sutures. It should, however, be stated that Ruzhencev (1940, p. 288) disagrees with these conclusions.

Stratigraphically *Peritrochia* is known to range from well down in the Upper Carboniferous into the Middle Permian, and geographically it is widespread in the western and southwestern part of the United States and has been found to occur also in Sicily, Crimea, the Ural region, the Pamir Highlands, and Timor. Only one species occurs in the Finis shale.

PERITROCHIA GANTI (Smith)
Plate 34, figures 1–4

Popanoceras ganti SMITH, 1903, U. S. Geol. Survey. Mon. 42, pp. 16, 132–133, 138, 146, pl. 21, figs. 14–16.

Stacheoceras ganti SMITH, 1913, Zittel-Eastman Text-book of paleontology, 2d ed., vol. 1, p. 641, text fig. 1213; BÖSE, 1919, Texas Univ. Bull. 1762, pp. 36, 37, 133, 134, 138, 140, 144; PLUMMER and MOORE, 1922, *idem.* 2132, pp. 146, 149, 150, 220; ? SMITH, 1927, U. S. Geol. Survey. Prof. Paper 141, pl. 20, figs. 18–20.

Marathonites ganti SMITH, 1927, Nederlandsch-Indië Jaarb. Mijnw., Jaarg. 55 (1926), Verh. 1, p. 45; [part?] ——, 1929, Am. Jour. Sci., 5th ser., vol. 17, pp. 67, 80; ? ——, 1932, U. S. Geol. Survey. Prof. Paper 167, p. 24, pl. 43, figs. 18–20; PLUMMER, 1937, Am. Jour. Sci., vol. 233, p. 465; [part] —— and SCOTT, 1937, Texas Univ. Bull. 3701, pp. 17, 30, 133, 138, 145–146, 147, text fig. 88 (opp. p. 402), pl. 31, figs. 1–5, 8, 9 [not 6, 7]; RUZHENCEV, 1940, URSS Acad. Sci., Paléont. Inst. Trav., t. 11, liv. 3, pp. 89, 92, 126, 127.

?Marathonites sp., SCOTT and ARMSTRONG, 1932, Texas Univ. Bull. 3224, p. 39.

Marathonites sulcatus [part] PLUMMER and SCOTT, 1937, Texas Univ. Bull. 3701, pp. 18, 139, 143–144, text fig. 88 (opp. p. 402), pl. 31, figs. 14–18.

? Vidrioceras moorei [part?] PLUMMER and SCOTT, 1937, Texas Univ. Bull. 3701, pp. 131, 132–133, 134, text fig. 88 (opp. p. 402), pl. 30, figs. 8–12.

Peritrochia ganti [part] MILLER and FURNISH, 1940, Geol. Soc. America Special Paper 26, p. 128; [part?] SHIMER and SHROCK, 1944, Index fossils of North America, p. 577, pl. 236, figs. 20, 21; [part?] MILLER and YOUNGQUIST, 1947, Kansas Univ. Paleont. Contr., Mollusca, Art. 1, p. 12.

This species has been described in detail by Smith and by Plummer and Scott, but the numerous specimens now available for study enable us to make certain additions to their discussions. The living chamber is at least one full volution in length, and the conch attains a maximum diameter of at least 35 mm. and a corresponding height and width of about 20 mm. and 21 mm., respectively. The umbilicus is small, inconspicuous, and closed.

The surface of the test bears transverse lirae which form broad shallow rounded ventral sinuses and similar lateral salients. Also, on exceptionally well preserved individuals, there are longitudinal lirae and the test is therefore reticulate. The longitudinal lirae are, however, not quite as well developed as are the transverse ones, particularly on the ventral zone of the conch. The sinu-

ous transverse constrictions, which are essentially parallel to the growth lines are recognizable on the exterior of the test, but they are not nearly as prominent there as on the internal mold. The shape of the sutures is shown by text figure 8.

Remarks.—This form is one of a group of species that is both abundant and widespread in the Upper Carboniferous and Lower Permian. Minor differences in the sutures and the shape of the conch have been used to differentiate species within the group. The species under consideration is characterized by the narrowness of the dorsal lobe of its sutures and by the fact that its umbilicus is very small. Minor differences in the denticulation of the sutures are not of specific value in this group for such differences are present on opposite sides of individual specimens.

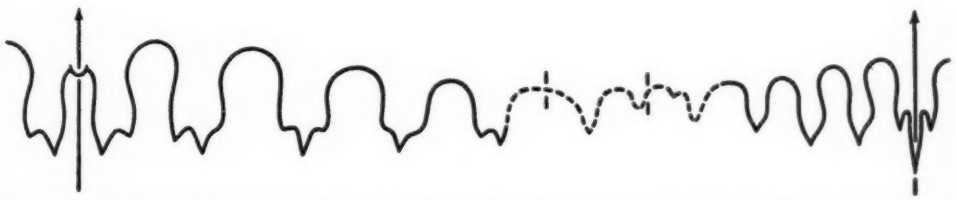


FIG. 8—Diagrammatic representation of a mature suture of *Peritrochia ganti* (Smith) where the conch is some 16 or 17 mm. in diameter, based on a specimen (S. U. I. 1062) from the Finis shale about 3½ miles east of Jacksboro, Texas, ×5.

Vidrioceras moorei Plummer and Scott of the Caddo Creek and Graham formations of north-central Texas may be synonymous with *P. ganti*. In their text, Plummer and Scott (1937, p. 133) stated that it is based on "cotypes." However, on the legend of their plate 30 they designated as a "holotype" a small specimen, some 8 mm. in diameter, from the Wayland shale about 5½ miles northwest of Chico, Wise County, Texas; and they stated that it "may be a young form of *Marathonites sulcatus* in the *Vidrioceras* stage." This specimen should be carefully restudied for the only published illustrations of it do not reveal the details of the sutures.

Both the external and the internal sutures of *P. ganti* are closely similar to those of *P. sellardsi* (Plummer and Scott) of the Lower Permian of north-central and west Texas. Furthermore, the general proportions of the conch in these two species are about the same, but the younger form has a considerably larger umbilicus.

Externally *P. ganti* resembles rather closely *P. "j. p. smithi"* (Böse) of the upper part of the Gaptank formation of west Texas. However, the dorsal lobe of the sutures of that species is relatively broad. Such a criterion is difficult to use, but it seems to indicate a specific difference between the two forms. Böse's species was regarded by Miller and Furnish (1940, p. 122) as synonymous with *P. ganti*, and they inadvertently designated a specimen from west Texas as a topotype of Smith's species.

P. electraensis (Plummer and Scott) of the Lower Permian of north-central Texas also appears to be close to *P. ganti*. However, in the only published description of that species (Plummer and Scott, 1937, pp. 148–149) it is stated that the "whorls do not bear constrictions." The nature of its internal sutures is not known.

Occurrence.—As interpreted by us this species is known from only the Wayland and the Finis shales of north-central Texas, and possibly the Wabaunsee group of eastern Kansas (see Smith, 1929, p. 67; and Elias, 1933, p. 695). From the Finis, we have representatives of it at the following localities, all in Jack County: (1) 3½ miles east of Jacksboro (text fig. 8, and 18 unfigured specimens), (2) 3 miles southeast of Jacksboro (pl. 34, figs. 3, 4; and three unfigured specimens), and (3) 4 miles south of Jacksboro (pl. 34, figs. 1, 2; and two unfigured specimens). Also Plummer and Scott described and illustrated some conspecific individuals from the same shale about 6½ miles northeast of Jacksboro.

Repositories.—State University of Iowa,

1061 (pl. 34, figs. 3, 4), 1062 (text fig. 8), 1063, 1067, (pl. 34 figs. 1, 2), and 13819; and private collections of James P. Conlin of Ft. Worth and Ralph H. King of Wichita Falls.

Genus SHUMARDITES Smith, 1903

Genotype.—Shumardites simondsi Smith.

When this genus was established, it was based on four conspecific specimens from the Wayland shale near Graham, Texas; and no other very similar forms were known. Since then much comparable material has been collected from the Pennsylvanian of eastern, central, and southwestern United States, the Upper Carboniferous of northwestern Africa and Greece, and the Late Paleozoic of central European Russia, the Ural region, and central Asia (Fergana and Tien Shan). A number of generic and specific names have been proposed for the specimens from these widely separated localities. The literature contains discussions of most of them by various authors, but there is little unanimity of opinion regarding their relations.

Although we have a great many American specimens available to us, we do not have any from the eastern hemisphere. Because we cannot make direct comparison, we believe that, for the present at least, it is best for us to confine our remarks largely to the material at hand. All specimens from the Finis shale appear to represent only three species, one of which is closely related to the genotype of *Shumardites*, whereas the other two belong in the genus *Vidrioceras*.

SHUMARDITES CUYLERI (Plummer and Scott)

Plate 35, figures 7–10

? *Shumardites* sp. SCOTT and ARMSTRONG, 1932, Texas Univ. Bull. 3224, p. 39.

Shumardites cuyleri PLUMMER and SCOTT, 1937, Texas Univ. Bull. 3701, pp. 18, 293, 295, 296, 297–298, 301, text fig. 88 (opp. p. 402), pl. 23, figs. 10–12.

Parashumardites cuyleri RUZHENCEV, 1939, URSS Acad. Sci. C. R. (Doklady), vol. 23, no. 8, pp. 850, 852; ——, 1939, URSS Acad. Sci., C. R. (Doklady), vol. 24, no. 8, pp. 835, 836.

Neoshumardites? cuyleri MILLER and FURNISH, 1940, Geol. Soc. America Special Paper 26, p. 77; MILLER and STURGEON, 1946, Jour. Paleontology, vol. 20, p. 387.

Only a single specimen of this species has been described previously. However, it shows the shape of both the internal and external mature sutures.

The collections we have available for study contain 35 specimens from the same shale as the holotype, that is, the Finis shale. They show that the phragmacone attained a diameter of at least 60 mm. and a corresponding height and width of conch and diameter of umbilicus of about 27 mm., 34 mm., and 26 mm., respectively.

At full maturity, the surface of the internal mold is essentially smooth and devoid of markings other than the sutures. However, during earlier growth stages, it is marked by prominent rounded transverse constrictions which form broad rounded ventral salients and similar but smaller dorsolateral sinuses. These constrictions, which become obsolete by the time the conch has attained a diameter of about 32 mm., for the most part do not extend dorsad of the umbilical shoulders; but on well preserved

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EXPLANATION OF PLATE 35

All specimens are from the Finis shale of north-central Texas.

FIGS. *1, 2—Vidrioceras uddeni* Böse. A large phragmacone (S. U. I. 1896) from 3 miles southeast of Jacksboro, ×2. (p. 214)

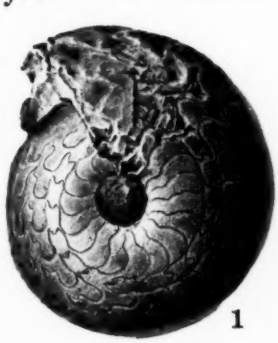
3—Schistoceras hildrethi (Morton). Part of an internal mold of a phragmacone (J. P. C. 3654) from about 3½ miles east of Jacksboro, ×1½. (p. 206)

4, 5—Vidrioceras conlini Miller and Downs, n. sp. The holotype (J. P. C. 3584) from the same locality as the preceding, ×2. (p. 216)

6—Eothalassoceras caddoense (Plummer and Scott). A moderately large almost complete internal mold (J. P. C. 3588), from the same locality as figure *3*, ×1½. (p. 207)

7–10—Shumardites cuyleri Plummer and Scott. Specimens from about 3½ miles east of Jacksboro. *7, 8*, An early mature phragmacone (J.P.C. 1999), ×2; *9, 10*, a fully mature, completely septate specimen (U.S.N.M.), ×1. (p. 212)

11, 12—Agathiceras ciscoense Smith. A large testiferous individual (S.U.I. 13764), from the Rock Island Railroad cut about 3½ miles southeast of Jacksboro, ×1½. (p. 209)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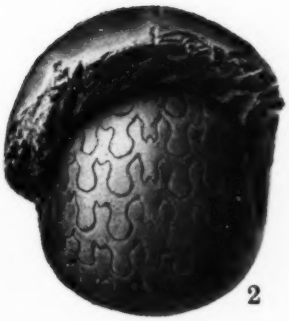
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Miller and Downs, Pennsylvanian ammonoids

individuals indefinite continuations of them can be discerned on the umbilical walls. These exceptional specimens also retain traces of the increments of growth, which are essentially parallel to the constrictions.

Fragments of the test which adhere to some specimens show that its surface bears fine growth lines and similar longitudinal lirae and is therefore reticulate. The longitudinal lirae seem to be particularly prominent on the portions of the test which border the umbilical shoulders. They do not, however, seem to be discernible on the internal mold, and the transverse markings there are of the nature of faint rounded grooves which are much broader than the growth lines.

Throughout ontogenetic development, the sutures continue to increase in complexity. As shown by text figure 9A, at a diameter of about 5 mm., at least the external sutures are similar to those of mature representatives of *Eoasianites*. Then they pass through a *Neoshumardites* stage (fig. 9B) when the conch has attained a diameter of some 15 mm., and in very large individuals (figs. 9C, 10B) they are about like those of early mature representatives of the genotype of *Shumardites*, *S. simondsi* Smith (cf. text figs. 9C, 9D; 10B, 10C).

Remarks.—The specimen which Miller and Unklesbay (1943, p. 23, pl. 3, fig. 6) referred to this species came from about 4¾ miles northwest of Jacksboro, Texas, presumably from the Wayland shale; and it therefore probably belongs in *S. simondsi*. Throughout ontogenetic development the sutures of that species are considerably more advanced than are those of equal-sized representatives of *S. cuyleri*, and at full maturity they are much more complex than are those of even the largest individuals of the species we are studying (cf. text figs. 9C and 9E).

The private collection of James P. Conlin of Ft. Worth contains a single specimen (No. 3133) from the Caddo Creek formation about 5½ miles west of Chico, Wise County, Texas. It is not very complete, but its maximum diameter measures about 24 mm. It has a considerably smaller umbilicus than do typical representatives of *S. cuyleri* and also its sutures are distinctly more primitive. Presumably this specimen is referable to *Preshumardites stainbrooki* Plummer and

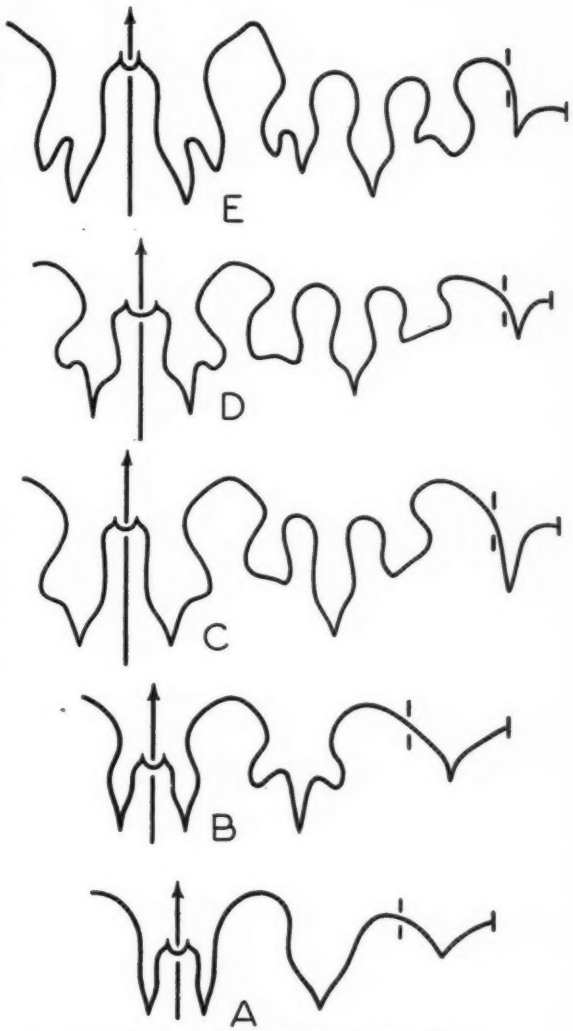

FIG. 9—External sutures of *Shumardites cuyleri* Plummer and Scott of the Finis shale of Texas and *S. simondsi* Smith of the Wayland shale of the same state. **(A)** Adolescent suture (*Eoasianites* stage) of *S. cuyleri* at a height of conch of about 1½ mm., ×12 (S. U. I. 1902—from about 3½ miles east of Jacksboro). **(B)** Early mature suture (*Neoshumardites* stage) of *S. cuyleri* at a height of conch of about 3 mm., ×4⅛ (same specimen as pl. 35, figs. 7, 8—adapical suture of outer volution). **(C)** Late mature suture of *S. cuyleri* at a height of conch of about 25 mm., ×1⅛ (same specimen as text fig. 10B—J. P. C. 3596). **(D)** Early mature suture of *S. simondsi* at a height of conch of about 9½ mm., ×3⅛ (same specimen as text fig. 10C—S. U. I. 1068). **(E)** Late mature suture of *S. simondsi* at a height of conch of about 38 mm., ×4 (adapted from J. P. Smith).

Scott, the only known representative of which came from the same horizon and locality, and that species should probably be referred to Ruzhencev's genus *Neoshumardites*.

The specimen from the Allegheny of eastern Ohio which Miller and Sturgeon (1946, pp. 386–387, pl. 56, fig. 12) called "*Neoshumardites* sp." is so incomplete and crushed that satisfactory comparisons can not be made with it. However, it is probably a little more primitive than *S. cuyleri*, and, if that is the case, it is more or less intermediate between typical *Neoshumardites* and typical *Shumardites*.

Occurrence.—The collections we are studying contain representatives of this species from the Finis shale at the following localities, all in Jack County, Texas: (1) 4 miles east-northeast of Jacksboro, (2) Ramzy and Riley ranches about 3½ miles east of the same town [many specimens], and (3) about 6½ miles east of Jacksboro. The holotype came from the same shale about 6½ miles northeast of Jacksboro.

Repositories.—State University of Iowa, 1071, 1901, 1902 (text fig. 9A), 1903. U.S. National Museum (pl. 35, figs. 9, 10). Private collections of James P. Conlin of Ft. Worth, 1999 (pl. 35, figs. 7, 8; and text fig. 9B), 3596 (text figs. 9C, 10B) and many other specimens; and of Ralph H. King of Wichita Falls and Merrill A. Stainbrook of Brandon (Iowa).

Genus VIDRIOCERAS Böse, 1919

Genolype.—Vidrioceras uddeni Böse.

Smith (1927, pp. 44–45) and Miller and Furnish (1940, p. 123) have expressed the opinion that *Vidrioceras* should be suppressed as a synonym of *Shumardites;* but Schindewolf (1931, p. 201) and Ruzhencev (1940, pp. 287–288) have disagreed with this conclusion. A comparison of text figures 10C and 10D makes it clear that the sutures of the genotype of *Vidrioceras* are more advanced than those of the type species of *Shumardites*, for the three subdivisions of the first lateral lobe of the external sutures have become essentially independent lobes and a small lobe has been added just outside the umbilical shoulder. We are therefore regarding Böse's genus as independent from *Shumardites*, but we suspect that these two genera are much more closely related than Plummer and Scott (1937, pp. 129–132, 287–288) and Ruzhencev (1940, pp. 287–288) believed. Böse (1919, pp. 146–148) regarded *Vidrioceras* as a subgenus of *Marathonites* [=*Peritrochia*], but Miller and Furnish, and Ruzhencev placed these two in different families, and Schindewolf, and Plummer and Scott regarded them as generically distinct.

The Finis shale contains only two species of this genus. One of them seems to be identical with the genotype, which was originally described from the upper part of the Gaptank formation of west Texas; and the other is very closely related to it.

VIDRIOCERAS UDDENI Böse

Plate 35, figures 1, 2

Vidrioceras uddeni BÖSE, 1919, Texas Univ. Bull. 1762, pp. 18, 36, 146, 149–152, 153, 154, pl. 7, figs. 40–61; PLUMMER and SCOTT, 1937, Texas Univ. Bull. 3701, pp. 22, 32, 131, 132, 133, 134, 135–136, text fig. 88 (opp. p. 402), pl. 30, figs. 1–7.

Shumardites uddeni SMITH, 1927, Nederlandsch-Indië Jaarb. Mijnw., Jaarg. 55 (1926), Verh. 1, p. 44; MILLER and FURNISH, 1940, Geol. Soc. America Special Paper 26, pp. 13, 122, 124, 125, 126.

We are referring to this species two specimens from the Finis shale and five from the Wayland shale at near-by localities in north-central Texas. After a direct comparison of these seven individuals with topotypes from the Gaptank formation of west Texas, it seems clear that the general physiognomy of the conch and the size and shape of the umbilicus is essentially the same in every case. Furthermore, the only appreciable difference in at least the external sutures of the west Texas and the north-central Texas individuals seems to be in the relative prominence of the small lobe just outside the umbilical shoulder (cf. text figs. 10D and 11C). It appears to be better developed in the topotype material, but we are inclined to doubt that this slight difference should be accorded any taxonomic significance.

Unfigured portions of the living chamber of the specimen we are illustrating show that it is at least two-fifths of a volution in length. Fragments of the test adhere to these pieces of the internal mold of the living chamber. They show that it bears moder-

ately coarse sinuous transverse markings, which form broad shallow rounded ventral salients, similar but smaller ventrolateral sinuses, and still smaller lateral salients.

Böse's figured types of this species (internal molds) bear sinuous transverse constrictions, and so do the equal-sized (small) specimens we are referring to it. However, our larger specimens indicate that these become less prominent and then obsolete during ontogenetic development, and none is visible on relatively large individuals like the one we are illustrating.

Occurrence.—This species was originally described from the upper portion of the Gaptank formation of west Texas. In 1937 Plummer and Scott referred to it some small specimens from the Caddo Creek formation of north-central Texas, and we are placing in it a few specimens from the Finis and Wayland shale members of the Graham formation of north-central Texas. From the Finis we have one representative from each of the following two localities in Jack County: (1) 3½ miles east of Jacksboro, and (2) 3 miles southeast of the same town.

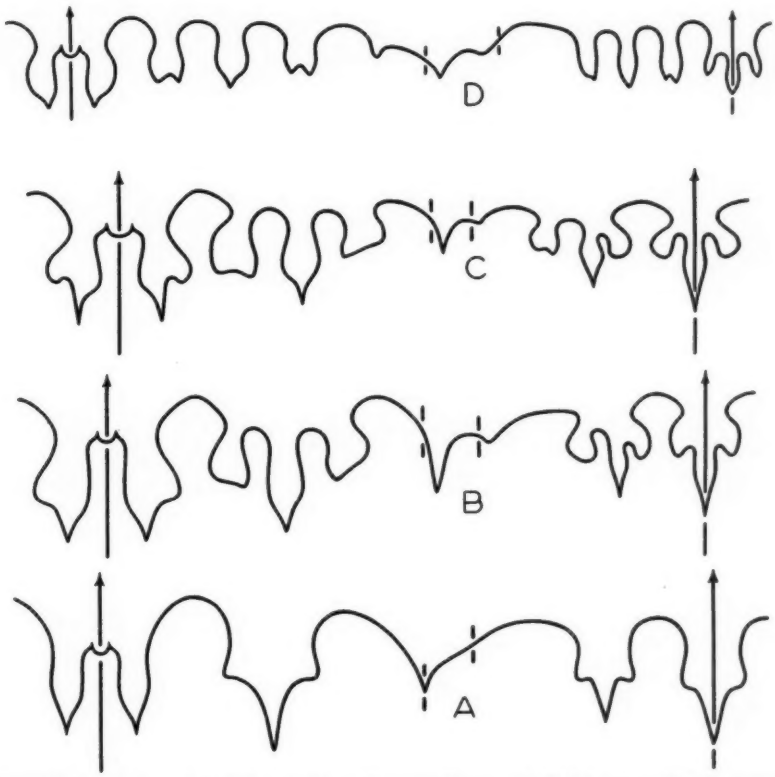

FIG. *10*—Complete sutures of *Neoshumardites*, *Shumardites*, and *Vidrioceras*. **(A)** Composite mature suture (with calculated proportions, so that internal and external portions of suture do not represent exactly same stage of ontogenetic development) of the genotype of *Neoshumardites*, *N. triceps* Ruzhencev of the Artinskian of the Ural region, at a height of conch of a little less than 10 mm., ×3½ (adapted from Ruzhencev). **(B)** Late mature suture of *Shumardites cuyleri* Plummer and Scott of the Finis shale about 3½ miles east of Jacksboro, Texas, at a height of conch of about 25 mm., ×1½ (based on J. P. C. 3596). **(C)** Early mature sutures of *Shumardites simondsi* Smith of the Wayland shale about 6½ miles northwest of Jacksboro, Texas, at a height of conch of about 9½ mm., ×3 (based on S.U.I., 1068). **(D)** Mature suture of the genotype of *Vidrioceras*, *V. uddeni* Böse of the Gaptank formation at Wolf Camp in the Glass Mountains of west Texas, at a height of conch of about 8½ mm., ×3½ (based on S. U. I. 1395).

Repositories.—State University of Iowa, 1896 (pl. 35, figs. 1, 2); and private collection of James P. Conlin of Ft. Worth.

VIDRIOCERAS CONLINI Miller and Downs, n. sp.
Plate 35, figures 4, 5

Although we are basing this species primarily on the figured specimen, which we are designating as the holotype, three additional ones are available for comparisons. Two of these (and the holotype) came from the Finis shale, whereas the other is from the slightly younger Wayland shale—both of these shales are members of the Graham formation.

The conch is globular in shape, and the phragmacone attains a diameter of at least 28 mm. Where the holotype, which is septate throughout, is about 20 mm. in diameter, its conch is about 19 mm. wide and almost 10 mm. high, and the umbilicus is some 4 mm. in diameter.

The test bears traces of the increments of growth. These form broad rounded ventral salients and on either side of them similar but smaller ventrolateral sinuses and lateral salients. Also, on at least the internal mold (and probably to a less extent the exterior of the test) there are prominent rounded sinuous transverse constrictions, which are parallel (or essentially so) to the growth

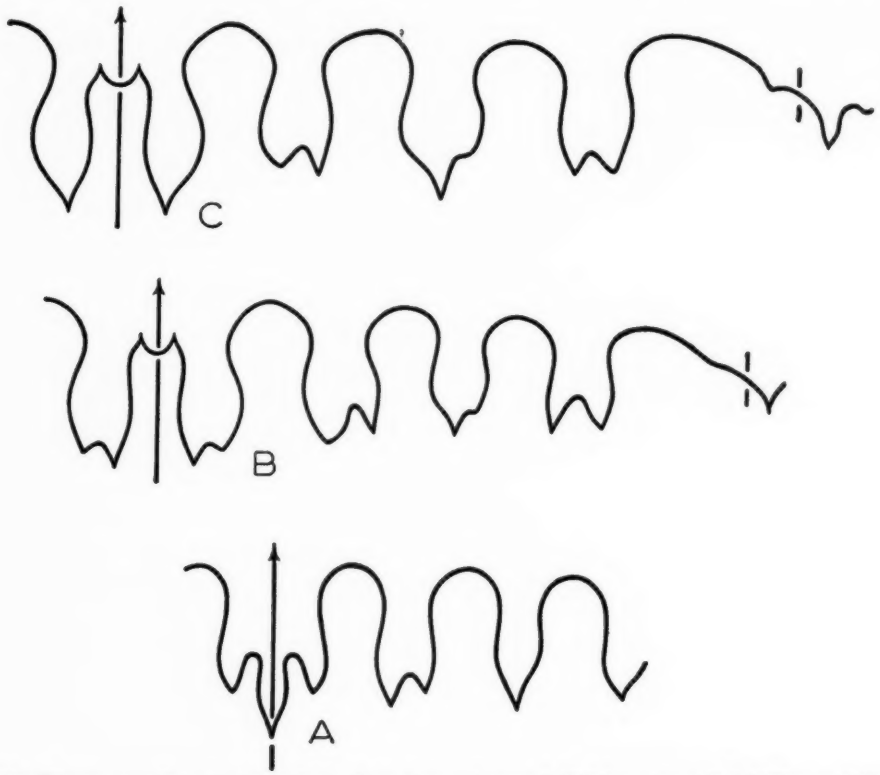

FIG. *11*—Diagrammatic representations of mature sutures of *Vidrioceras conlini* Miller and Downs **(A, B)** and *V. uddeni* Böse **(C)**. The first **(A)** represents part of an internal suture where the conch is about 27 mm. in diameter, and it is based on a specimen (S. U. I. 13822) from the Wayland shale about 3½ miles northwest of Jacksboro, Texas, ×2. The second **(B)** is based on the holotype represented by figures 4, 5 on plate 35, and it portrays the shape of the external suture when the conch had attained a diameter of about 20 mm., ×6. The third **(C)** is based on the specimen represented by figures 1, 2 on the same plate, and it shows the nature of the external suture where the diameter of the conch measures some 16 mm., ×7.

lines. These constrictions are present on even the adoral portion of large individuals, and there are about three of them to a volution.

The shape of the sutures at maturity is shown by text figures 11A and 11B. The portion of the internal sutures (text fig. 11A) is not based on the holotype but on a slightly larger specimen from a little higher stratigraphic horizon (the Wayland shale), and that specimen seems to have a somewhat narrower conch. The difference in the shape of the conch of these two individuals may, however, be due to difference in ontogenetic stage of development.

Remarks.—This species is very similar in size and shape of conch and umbilicus to the genotype of *Vidrioceras, V. uddeni* Böse. Also, its external, and the known portion of its internal, sutures are in many ways strikingly similar to those of that species (cf. text figs. 10D and 11A–C). However, the prongs of the ventral lobe are bifid in this species but not in the genotype, and the relative prominence of the small lobe just outside the umbilical shoulder is different in the two. Also, even large individuals of the form under consideration have prominent sinuous constrictions, whereas such constrictions become obsolete during early maturity in at least the specimens from north-central Texas that we are referring to the type species.

In certain respects, the holotype of *V. conlini* resembles that of *V. moorei* Plummer and Scott of the Caddo Creek formation, which is only slightly older than the Finis shale. However, Plummer and Scott's holotype is small and probably represents only the immature portion of the conch.

Occurrence.—Finis and Wayland shale members of the Graham formation of north-central Texas. All three of the specimens known from the Finis came from about 3½ miles east of Jacksboro, and that known from the Wayland was found about 3½ miles northwest of the same town.

Types.—State University of Iowa, 13822 (from the Wayland shale); and private collections of James P. Conlin of Ft. Worth, 3583 (unfigured paratype) and 3584 (holotype), and of Ralph H. King of Wichita Falls (unfigured paratype).

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SOME DEVONIAN SPIRIFERIDAE FROM ALBERTA[1]

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ABSTRACT—One new genus including five new species of Spiriferidae, hitherto confused with *Mucrospirifer*, are described from the new oil fields of Alberta, Canada, from late Middle and early Upper Devonian formations.

INTRODUCTION

FOR some time, *mucronatus*-like species of *Spirifer, sensu lato*, have been found in the Devonian of Alberta, and the Middle Devonian correlation suggested by them has been at variance with accepted correlations. For instance, the Waterways formation hitherto commonly accepted as early Upper Devonian contains these *mucronatus*-like species. The Hay River shale, entirely Upper Devonian, and in part, at least, not earlier than mid-Upper that is, late Senecan to Chautauquan (late Frasnian to Famennian) contains them in abundance. Recently they have been found in borehole cores from the Leduc and Redwater oilfields whence, crossing my desk in the course of business routine, they have become my responsibility as a correlational problem.

Specimens of these questionable "*Mucrospirifer*" species have now been critically compared with examples of *M. mucronatus* Conrad and closely congeneric forms kindly sent by Prof. C. O. Dunbar of Yale University and Dr. G. A. Cooper of the United States National Museum, and it has been found that, though superficially similar in being exaggeratedly transverse, mucronate and lamellose, they show no positive evidence of genetic relationship with the typically east American Middle Devonian *Mucrospirifer mucronatus* stock. In fact, they show no close relationship with the type of any named genus, and are apparently peculiar to northwestern North America where little is known, comparatively, of the Devonian faunas.

[1] Approved for publication by the Manager, Exploration Department, Imperial Oil Ltd., Calgary, Alberta, Canada.

The requirements of petroleum exploration and of oil field geology make it imperative to work out the relationships and correlation of these and other elements of the Devonian faunas in Alberta. It is my purpose in this article to make a beginning in this task, commencing with a formal description of a new genus and species of mucronate Spiriferidae.

All primary types of the new species described below are in the possession of Imperial Oil Ltd., Calgary, Alberta, Canada.

SYSTEMATIC PALEONTOLOGY

Class BRACHIOPODA
Superfamily SPIRIFERACEA
Family SPIRIFERIDAE
Genus ELEUTHEROKOMMA Crickmay, n. gen.

Genotype.—Eleutherokomma hamiltoni Crickmay, n. sp.

Description.—Medium sized, subequally biconvex, strongly transverse and mucronate Spiriferidae, with non-plicate fold, and sulcus and costate (or plicate) lateral slopes. Hinge line straight and equal to the greatest width of the valve.

Ventral valve with short interarea, medium broad delthyrium and incurved beak; interiorly with strong straight dental lamellae diverging toward their bases, with long straight hinge teeth and in some, a small adventitious deposit of nacre producing in some specimens the appearance of a transverse delthyrial plate but not a true plate; usually possessing a low, thin, sharp median ridge but not a true septum.

Dorsal valve with very short interarea and low, sharp beak; interiorly with deep, narrow sockets and strong oblique socket plates, a short, broad, rounded, undivided,

vertically striate cardinal process and a low median ridge but not a true septum.

Exterior of lateral slopes ornamented by few to many costae (or plicae); and, on the whole shell, concentric lamellae. Micro-ornament of whole shell (except interarea), fine radial threads (or striae) crossed by fine, regular concentric micro-fila and, in some, irregularly spaced micro-spines.

Distinction from most other spiriferid genera lies in the exaggeratedly transverse and mucronate character. From *Mucrospirifer*, as from all other genera, it is separated by its complex micro-ornament.

ELEUTHEROKOMMA HAMILTONI Crickmay, n. sp.
Plate 36, figures 1–3

Description.—Shell somewhat smaller than other species, subequally biconvex, approximately semicircular in outline, each extremity produced sharply into a very long, slender, needle-like mucro. Lateral slopes with eight to ten rounded costae and narrower furrows, the strength of the costae decreasing gradually with distance from fold and sulcus. Costae show weakly on internal surface of shell.

Ventral valve strongly convex. Sulcus bounded by very strong costae, somewhat narrow, deep, marked by a faint trace of a median costa within it. Beak strongly incurved. Interarea short. Delthyrium about 60 degrees, open except for a small, irregularly developed adventitious deposit of nacre which forms a callus and which in many shells resembles a transverse delthyrial plate. Hinge teeth long, sharp, straight. Dental lamellae strong, somewhat short (less than one-fourth length of valve), diverging strongly toward their bases, diverging from beak parallel to second costa. Internal surface with a low, blunt median ridge through central region of valve.

Dorsal valve somewhat less convex, more rounded, less angular. Fold narrow, not specially prominent, non-plicate except at anterior commissure, where a faint trace of a median furrow appears. Beak low, inconspicuous. Interarea very short, Notothyrium wide and very short. Cardinal process small, low, rounded, vertically finely striate. Socket plates very large and massive. Rostral chamber filled with more or less adventitious nacre. There is no dorsal median ridge.

The exterior surface (except that of the palintrope) is covered with fine concentric lamellae spaced 3.5 to the millimeter, more closely spaced at the anterior edge, each lamella projecting about 0.2 to 0.3 mm. above the general surface. Between each pair of lamellae there are four to six concentric micro-fila of remarkable continuity, fineness and regularity, numbering fourteen to twenty to the millimeter. Surface (except interarea) also covered with fine radial threads (micro-striae), about twelve to sixteen to the millimeter.

Measurements.—Holotype, width, 42 mm.; length, 9 mm.; depth (ventral valve), 3 mm.

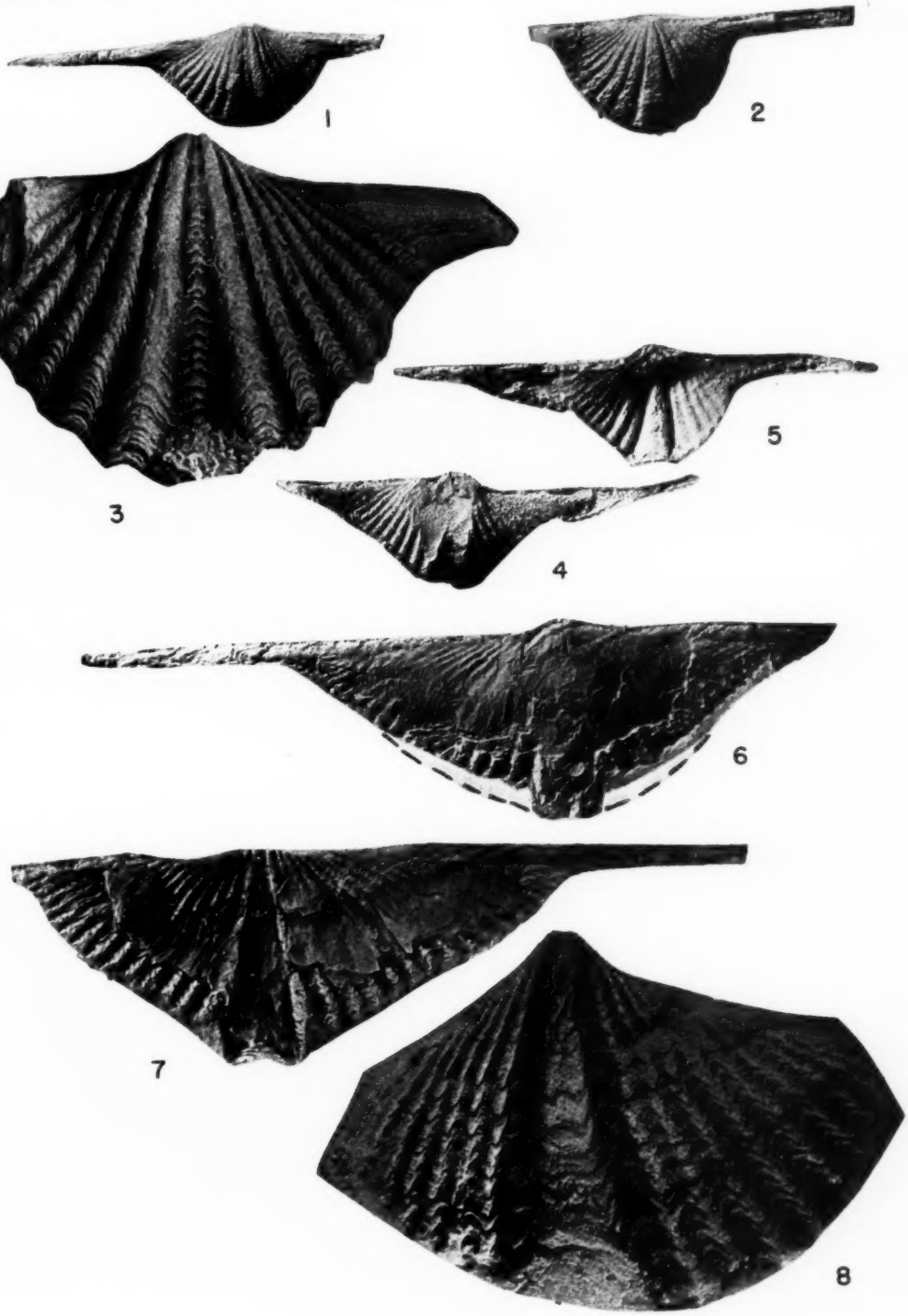
Occurrence.—*E. hamiltoni* occurs in the

EXPLANATION OF PLATE 36

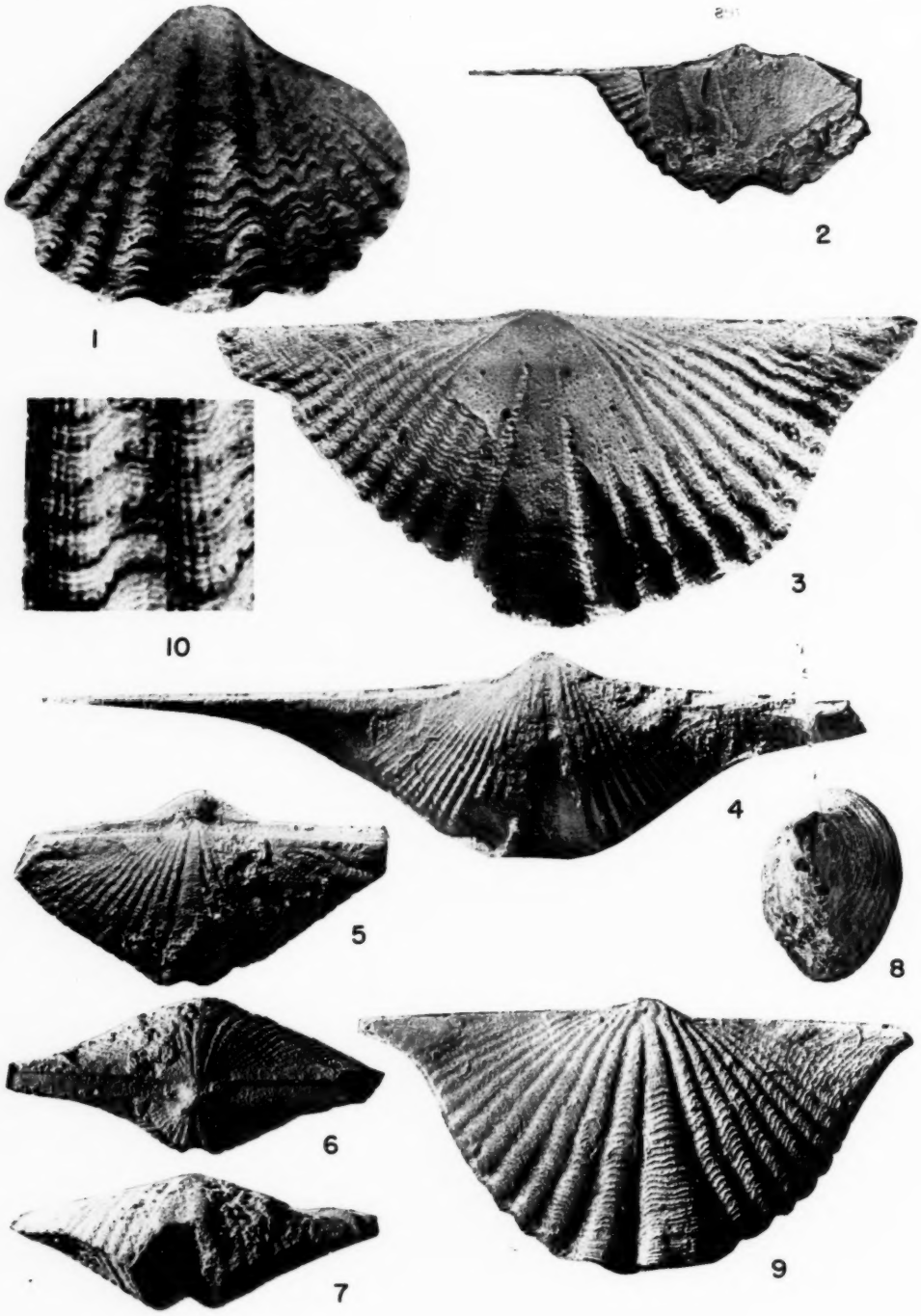
FIGS. *1–3*—*Eleutherokomma hamiltoni* Crickmay, n. sp. *1*, Holotype, from La Saline Rock, pedicle valve, external aspect. Left mucro fully preserved, right broken off at less than mid-length. ×1.8. *2*, Paratype No. 1, from La Saline Rock, brachial valve, external aspect. Both mucrones broken off; impression of right mucro is preserved for about $\frac{7}{8}$ of its full length. ×2.0. *3*, Paratype No. 2, from La Saline Rock, pedicle valve, external aspect, magnified to show micro-ornament, ×5.0. (p. 220)

4–5—*Eleutherokomma killeri* Crickmay, n. sp. *4*, Holotype, from Imperial Egremont No. 1 well at 4430–4446 feet depth, mold of interior of a pedicle valve, with part of the right mucro of the brachial valve of the same individual. The mucrones are mostly, but not perfectly, preserved. ×1.5. *5*, Holotype, reverse of same specimen, ×1.6. (p. 222)

6–8—*Eleutherokomma leducensis* Crickmay, n. sp. *6*, Holotype, from Millet-Leduc No. 16-6 borehole at 6058–6078 feet depth, mold of interior of brachial valve with some shell substance showing ribbing and other surface marks attached to it in places. Outline completed in broken black line. Interior dorsal median ridge is faintly discernible. ×2.5. *7*, Holotype. reverse of same specimen. Some micro-ornament is shown as an impression in the matrix, ×2.8. *8*, Paratype No. 1, from same source, mold of part of exterior of a small pedicle valve. Specimen is a deeply concave impression. Magnified to show micro-ornament, ×5.5. (p. 222)



Crickmay, Devonian Spiriferidae



Crickmay, Devonian Spiriferidae

uppermost zone of the Waterways formation at La Saline Rock, w t bank of Athabasca River, sec. 15, T. 93, R. 10, west of 4th meridian (holotype). Also at a number of other lower Athabasca River localities.

Name.—After Frederick J. Hamilton, Geologist, Imperial Oil Ltd.

Age.—*E. hamiltoni* occurs with a considerable assemblage of *Stropheodonta* species including *S.* cf. *iowensis* Owen, *S.* cf. *dorsata* Stainbrook, *S.* cf. *costata* Owen, *S.* cf. *littletonensis* Stainbrook, *S.* cf. *quadratella* Stainbrook; with *Nervostrophia* sp. nov., "*Athyris angelica*" var. *occidentalis* Whiteaves, *Cyrtina billingsi* Meek, *C.* cf. *triquetra* Hall, *Atrypa bremerensis* Stainbrook, and *A. gigantea* Webster. Of these, the last named and the *Stropheodonta* species definitely indicate a correlation with the Cedar Valley fauna of Iowa, and in general with the Middle Devonian. Typical *Nervostrophia* is mainly, but not entirely, Upper Devonian, and at this locality and in this association it makes its earliest appearance in Alberta; its date here could hardly be much earlier than late Middle Devonian. *Cyrtina billingsi* is peculiar to this zone, and distinguishes it from the lower zones in the Waterways; it is very close to *C. missouriensis* Swallow from Cedar Valley equivalents. The species of "*Athyris*" is neither *Athyris* nor *angelica;* it appears to be close to "*Athyris vittata* Hall" from the Cedar Valley which is neither *Athyris* nor *vittata;* its exact date is not definitely indicated, although it connects the zone of *E. hamiltoni* with the subjacent zone of "*Acrospirifer*" *allani* Warren, the dating of which by Warren as early Upper Devonian I cannot bring myself to accept. "*A.*" *allani,* though somewhat removed from typical *Acrospirifer* which does not occur in North America (unless, as is possible, "*Spirifer*" *pinyonensis* Meek belongs), is unquestionably related to that genus. "*A.*" *allani* has all the internal structures of the genotype, *A. primaevus* Steininger, as well as the micro-ornament of radial threads without fringes (a distinction from the eastern American Lower Devonian "*Acrospirifer*" species); however, "*A.*" *allani* is very much narrower and neater than typical *Acrospirifer,* has a notably longer ventral palintrope and high, narrow delthyrium. If it is, as seems likely, a later development of the *Acrospirifer* stock, it is scarcely so different as to be very much later; it would be stretching probability to consider it to be later than late Middle Devonian. Furthermore, its zonal associates are *Atrypa albertensis* Warren, *A. clarkei* Warren, both peculiar to this zone and locality, *A.* cf. *independensis* Webster, *Spinocyrtia* cf. *capax* Hall, "*Athyris angelica*" var. *occidentalis* Whiteaves, *Centronella* sp. nov., "*Martinia*" *sublineata* Meek (=?*Martinia halli* Branson), which are probably species of *Ambocoelia. A. independensis* is typical of the basal Cedar Valley limestone, hence well down in the Middle Devonian at the latest. *Spinocyrtia capax* occurs in a higher zone in the Cedar Valley, and confirms the Middle Devonian correlation. The occurrence of the "*Athyris*" forms (which are not related to true *Athyris*) in both zones shows

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EXPLANATION OF PLATE 37

FIGS. *1–3, 10—Eleutherokomma beardi* Crickmay, n. sp. *1,* Paratype No. 2, from Imperial Paddle River No. 1 borehole, at 8090–8110 feet depth, mold of exterior of pedicle valve. The posterior margin is incomplete. Magnified to show micro-ornament, ×10.0. *2,* Paratype No. 1, from same source, mold of part of interior of pedicle valve, with some shell substance preserving the left mucro, ×3.0. *3,* Holotype, from same source, mold of exterior of brachial valve, with some shell substance still in place. The dorsal palintrope and the excessively fine mucrones have been lost in breaking the matrix. Magnified to show some of the micro-ornament, ×6.0. *10,* Paratype No. 3, a small portion of the surface more highly magnified to show micro-ornament, ×20.0. (p. 223)

4–9—Eleutherokomma reidfordi Crickmay, n. sp. *4,* Holotype, from Hay River, Northwest Territories, 14 miles from mouth, pedicle valve. Shell substance encrusted with minute coralline and bryozoan calcareous deposits. The left mucro is complete. ×2.2. *5–8,* Paratype No. 1, from same locality, a specimen with both valves, much encrusted, extremities broken, ×2.0. *5,* Dorsal aspect. *6,* posterior aspect. *7,* anterior aspect. *8,* left lateral aspect. *9,* Paratype No. 2, from same locality, brachial valve, external aspect. Both mucrones broken off. Magnified to show some micro-ornament, ×3.2. (p. 224)

that these zones are close in date, however distinct. *E. hamiltoni* may well indicate a zone in middle Erian (or not far below middle Givetian) or, in rougher terms, late, but not necessarily latest, Middle Devonian.

Eleutherokomma killeri
Crickmay, n. sp.
Plate 36, figures 4, 5

Description.—Shell of average size for the genus, subequally biconvex, angularly aliform in outline, with each extremity produced into a strongly tapering, needle-sharp mucro. Lateral slopes narrow, with nine to twelve fine, rounded costae and furrows of like width, strength of costae decreasing gradually with distance from fold and sulcus. Costae show strongly on internal surface of shell.

Ventral valve strongly convex. Sulcus narrow, bounded by strong costae, unmarked except by micro-ornament. Beak somewhat incurved. Interarea short. Delthyrium about 60 degrees, open except for a neat, linear callus upon the inner face of the dental lamellae; the two opposing calluses remaining discrete. Hinge teeth comparatively small. Dental lamellae somewhat variable in length from one-fourth to one-third the length of the valve, stout, diverging strongly both toward the bases and toward the anterior. There is no trace of a median ridge.

Dorsal valve only slightly less convex. Fold very narrow, but flaring broadly at its anterior end, prominent, its culmen flat to shallowly furrowed. Beak low, inconspicuous. Notothyrium wide, very short. Cardinal process very small, rounded, vertically striate. Sockets narrow. Socket plates thin. Entirely anterior to the umbonal region there is a low, thin, dorsal median ridge.

The exterior surface of the shell is covered with fine, close, concentric lamellae spaced 4.3 to the millimeter, with no approximation toward the anterior commissure. Between the lamellae there are very faint, fine, concentric micro-fila, almost too faint to be observed. The entire surface is also covered with fine radial threads (micro-striae), about ten to the millimeter.

Measurements.—Holotype, width 29 mm.; length, 10 mm.; depth (ventral valve), 3 mm.

Occurrence.—*E. killeri* occurs in the fine-grained limestone zone below the reefs, at a depth of 4430 to 4446 feet in Imperial Egremont No. 1[2] well, sec. 14, T. 58, R. 22, west of the 4th Meridian. It occurs also in Imperial Paddle River No. 1 borehole at 8420, 330 feet below *E. beardi*.

Name.—After Frederick A. Killer, Geologist, Imperial Oil Ltd.

Age.—The dating of this species is somewhat uncertain. From the evolutionary viewpoint, it appears to be advanced as compared with *E. hamiltoni*, although little developed as compared with *E. beardi*. It occurs in strata roughly contemporaneous with those that yield the two following species. Latest Middle to earliest Upper Devonian is indicated in the discussion of *E. beardi*. It is plainly earlier than the latter.

Eleutherokomma leducensis
Crickmay, n. sp.
Plate 36, figures 6-8

Description.—Larger than the average of the genus, subequally biconvex, strongly transverse, each extremity produced into a very long, slender mucro. Lateral slopes wide, flattened, with twelve to fifteen fine (or slender), rounded, prominent costae, which become increasingly slender with distance from fold and sulcus. Costae scarcely show on internal surface of shell.

Ventral valve strongly convex, somewhat angular. Sulcus bounded by strong costae, narrow, flaring at anterior edge, unmarked. Beak prominent, less incurved than in other species. Interarea notably longer than average of genus. Delthyrium about 50 degrees, open except for a very faint development of linear callus as in *E. killeri*. Hinge teeth strong. Dental lamellae strong, of considerable length (one-third length of valve), diverging widely toward anterior, parallel to third costa. A strong, sharp median ridge extends from near the beak across the central region of the internal surface.

Dorsal valve somewhat less convex; less angular. Fold narrow, prominent, with a broad but very shallow median furrow in its anterior half. Beak sharp, not very conspicuous. Interarea short. Notothyrium wide,

[2] Formerly known as Imperial Redwater No. 4.

short. Cardinal process low, flat, vertically striate. Socket plates large and massive. Umbonal region with little or no callus. A short, sharp median ridge extends anteriorly from the inferior edge of the cardinal process for a short distance.

The exterior surface (except the palintrope) is covered with fine concentric lamellae, spaced 2.3 to the millimeter, with some approximation at the anterior edge. Between each pair there are about six highly regular, concentric micro-fila. The surface is covered also with very fine radial threads (micro-striae), about fifteen to the millimeter, which cross the micro-fila, producing a microscopic quadrille pattern, and combine with the lamellae to produce a very fine fimbriate ornament.

Measurements.—Holotype, width 60 mm.; length (dorsal valve), 11 mm. (the corresponding ventral valve would be about 13 mm.); depth (dorsal valve), 2.5 mm.

Occurrence.—*E. leducensis* occurs in the fine limestone zone below the dark shale zone; that is, below the equivalents of the D3 reefs, at a depth of 6058 to 6078 feet in Millet-Leduc No. 16-6 borehole in sec. 6, T. 48, R. 24, west of the 4th Meridian. It occurs, although rarely in Imperial Egremont No. 1 well at 4440 feet with *E. killeri*.

Name.—From Leduc oilfield.

Age.—The remarks concerning the last-species apply also to this one. Latest Middle to earliest Upper Devonian is indicated in the discussion of *E. beardi*.

ELEUTHEROKOMMA BEARDI
Crickmay, n. sp.
Plate 37, figures 1–3, 10

Description.—Shell of about average size, subequally biconvex, somewhat semicircular in outline, with extremities produced into exceedingly fine aculeiform mucrones. Lateral slopes of medium width, with nine to twelve delicate, rounded costae, the strength of which decreases with distance from fold and sulcus. Costae show with considerable strength on the internal surface.

Ventral valve strongly convex. Sulcus bounded by strong costae, somewhat narrow, unmarked. Beak strongly incurved. Interarea short. Delthyrium about 60 degrees; open, without callus. Hinge teeth fine. Dental lamellae strong, diverging parallel to first furrow, about one-fourth the length of the valve.

Dorsal valve only slightly less convex. Fold somewhat wider than in other species, evenly tapered, prominent, flat upon the culmen. Beak slightly more prominent than in other species. Interarea very short. Notothyrium not wide; very short. Cardinal process rounded, vertically finely striate. Socket plates strong. A very inconspicuous internal median ridge occupies the central region of the valve.

The exterior surface is covered with fine concentric lamellae, spaced three to six to the millimeter. Between each pair are three or four exceedingly fine concentric micro-fila. The surface is covered also with fine radial threads (micro-striae), about ten or twelve to the millimeter. The intersection of these two sorts of fine ornament produces a sharp, though very delicate, fimbriate pattern, and, from some of the stronger intersections, short, delicate micro-spines arise.

Measurements.—Holotype, width, 42.5 mm.; length (dorsal valve), 9.5 mm. (the corresponding ventral valve would be 10.5 mm.); depth (dorsal valve), 3 mm.

Occurrence.—In the fine dark limestone zone, below the black shale, in Imperial Paddle River No. 1 borehole, at a depth of 8090 to 8110 feet, in sec. 17, T. 56, R. 8, west of the 5th Meridian.

Name.—After Gordon C. Beard, Geologist, Imperial Oil Ltd.

Age.—The dating of this species is only slightly more definite than that of the last two species, both of which occur in strata more or less contemporaneous with each other and with this. In the Imperial Paddle River No. 1 borehole the black shale zone occurs between depths of 7720 and 7980 feet, and contains *Tentaculites* sp., *Manticoceras* cf. *simulator* Hall, *Bactrites* sp., etc. This is thought to be of early Upper Devonian age, by comparison with the position of *Manticoceras simulator* in New York. *E. beardi* occurs below that, hence is older. Like *E. killeri* and *E. leducensis*, it is plainly later than *E. hamiltoni*. Possibly it can be dated tentatively as latest Middle or earliest Upper Devonian. *E. killeri* is somewhat earlier, occurring 330 feet deeper at Paddle River. *E. leducensis*, a companion of *E. killeri*, is also earlier.

ELEUTHEROKOMMA REIDFORDI
Crickmay, n. sp.
Plate 37, figures 4–9

Description.—Shell of average size or larger, subequally biconvex, angularly aliform in outline, with very tapering extremities, produced into very long, needle-like mucrones. Lateral slopes wide, with eighteen to thirty rounded costae and slightly narrower furrows. Costae decrease in strength with distance from fold and sulcus; beyond the twelfth costae, they decrease greatly in length, tending to run not radially but parallel. On the internal surface of the shell, costae show mainly toward the anterior edge; they are faint or absent in other regions. Shell substance thick.

Ventral valve strongly convex. Sulcus of average width, evenly tapered, deep, sloping within to a narrow bottom, unmarked. Beak strongly incurved. Interarea short. Delthyrium about 50 degrees, open except for a regular, massive callus. Hinge teeth stout and long. Dental lamellae strong, about one-third the length of the valve, reinforced with considerable callus in the umbonal cavities and with a very regular callus in the delthyrial chamber, diverging strongly toward their bases, and diverging from the beak parallel to the second costa. Low median ridge only in young stages.

Dorsal valve only slightly less convex. Fold somewhat narrow, slightly flaring, marked throughout most of its length from the anterior end by a shallow furrow. Beak stronger and slightly more conspicuous than in other species. Cardinal process divided by a slight central concavity, vertically striate. Sockets short, deep, roundish. Socket plates massive, curved, and reinforced with considerable callus in the rostral cavity. Median ridge extremely variable in its development: strong in some specimens, confined to the neanic stage in others.

Exterior surface covered with fine, close, concentric lamellae, spaced about 4.5 to the millimeter on the average, although spacing is rather irregular, some being unaccountably closer or farther apart; in general they are farther apart on the umbonal region, and closer in the anterior region. Between the lamellae are two or three very faint, concentric micro-fila. The entire surface is covered with fine radial threads (micro-striae), about seven to ten per millimeter. In the average preservation they tend to obliterate the micro-fila and to give the lamellae a fimbriate edge.

Measurements.—Holotype, width, 59 mm.; length, 11.5 mm.; depth, 4 mm. Paratype No. 1, width not preserved; length, 16 mm.; length (dorsal valve), 5 mm.; depth, 6 mm.; depth (dorsal valve), 5 mm.

Occurrence.—In lower part of Hay River shale, on Hay River, Northwest Territories, fourteen miles above its mouth. Occurs also three miles farther up Hay River.

Name.—After Harry K. Reidford, Geologist, Imperial Oil Ltd.

Age.—E. reidfordi is advanced, from the evolutionary point of view, beyond the other species; this is most notable in certain ornament characteristics, such as increase in number of costae and the tendency to parallelism. It occurs in a zone directly subjacent to the earliest species of *Cyrtospirifer* which must be regarded as occurring well up in the Upper Devonian or Chemung (= late Senecan = late Frasnian). *E. reidfordi* cannot well be much earlier, since it is later than the "black shale" zone; it may therefore be of Finger Lakes age (early to mid-Frasnian).

GENERAL CORRELATIONS

Eleutherokomma ranges from later Middle into earlier Upper Devonian. There are named species and others that in due time will find their proper assignment to it. In view of its established stratigraphic range in the plains region of Alberta and in the Northwest Territories, *Eleutherokomma* should be looked for in the foothills and Rocky Mountain sections of Canada, where, so far, it has not been definitely identified, but where it may be expected directly above and directly below the Blackface Mountain shale, a "black shale" equivalent. It should be sought in late Middle and early Upper Devonian zones of the western United States, even as far east as Iowa and Missouri, in such formations as the Cedar Valley and the Shellrock, for there is abundant positive evidence (in part cited herein) of close Middle Devonian marine connection

between Alberta, including the northwest part of the province, and the Iowa basin. There is no genuine evidence of any connection in the Middle Devonian between New York and either Iowa or Alberta. Citations of *Cyrtina hamiltonensis* from Alberta and *Athyris vittata* from Iowa as evidence of such a connection are in error for the reason that they are uncritical identifications.

While the origin of *Eleutherokomma* may not be very clear, there is at least, a long record of its existence in northwest America, where it is an established native element throughout the early Upper Devonian. If it is Asiatic and reached Alberta in the Middle Devonian, it had avenues of migration, however roundabout, even as far as New York in early Upper Devonian time.

JOURNAL OF PALEONTOLOGY, VOL. 24, NO. 2, PP. 226–228, PL. 38, 1 TEXT FIG., MARCH 1950

A NEW SILURIAN *HUGHMILLERIA* FROM WEST VIRGINIA

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ABSTRACT—A new eurypterid, based on three carapaces and detached abdominal segments, is described. The species, named *Hughmilleria bellistriata*, is from the Silurian Wills Creek formation of Hardy County, West Virginia. A complete list of described species of the genus *Hughmilleria* is included.

EURYPTERIDS are rare in the Appalachian region south of Pennsylvania. Records reveal only scattered occurrences restricted to West Virginia, Maryland and Virginia. None are known south of these states.

The first known eurypterid from this general region was reported by Shuler (1915, pp. 551–554) who described *Mixopterus (?) alveolatus* from the Ordovician Bays sandstone at Lyons Gap, Virginia. Tilton and others (1927, p. 262) identified *Eurypterus sp.* in the Silurian Wills Creek formation near Bass, Hardy county, West Virginia. The most important contribution to our knowledge of eurypterids of this area, however, was made by C. K. Swartz (1923, pp. 716–718) who described *Eurypterus flintstonensis* from the Silurian Tonoloway formation of Martin Mountain, Maryland, *Hughmilleria* sp. cf. *shawangunk* from the Silurian Wills Creek formation at Cumberland, Maryland, several fragments of a possible *Pterygotus* from the Silurian Keefer sandstone near Hancock, Maryland, and *Dolichopterus cumberlandicus* from the Wills Creek formation at Riverside and Cedar Cliff, West Virginia.

In the early part of 1948, the present writer visited the locality previously discovered by Tilton and collected several fragmentary eurypterids. These fossils are not common at this locality, but three carapaces, several abdominal segments and other small fragments were found. The carapaces and part of the abdominal fragments have been identified as representing a new *Hughmilleria*, here named *H. bellistriata*, which apparently was the commonest element of the fauna at this locality. A fragment of an undoubted *Pterygotus*, probably representing a small part of the coxa of the sixth appendage, indicates a form which probably reached an overall length of more than three feet. Another fragment representing the seventh joint of the sixth appendage of a *Eurypterus* was identified. The outline of this small fragment suggests a form not greatly unlike *Eurypterus remipes* DeKay of the Bertie waterlime of New York, but this determination is uncertain.

The writer wishes to thank Mr. D. S. Holdcroft, Tulsa, Oklahoma, who kindly furnished the photographs of the specimens described.

Class MEROSTOMATA (Dana) Woodward
Order EURYPTERIDA Burmeister
Family PTERYGOTIDAE Clarke and Ruedemann
Genus HUGHMILLERIA Sarle, 1902
HUGHMILLERIA BELLISTRIATA Kjellesvig-Waering, n. sp.
Plate 38, figures 1, 2. Text figure 1

The species is based on three carapaces and two mesosomatic segments. The holotype (plate 38, fig. 1) is preserved as a mold of the dorsal side of the carapace. The anterior margin has been destroyed, but the lateral eyes, ocelli, and almost the entire surface of the carapace, with well preserved ornamentation, is preserved. Another carapace (plate 38, fig. 2) is entirely preserved but greatly distorted. Its dorsal surface plainly shows two crushed eyes. Two imprints of *Lingula* are present which appear as lateral eyes on the carapace and give the specimen the erroneous appearance of being a *Eurypterus*. The true marginal *Hughmillerian* eyes, however, distinctly occur anterior to the two brachiopod imprints. Another unfigured carapace shows only the right half of the dorsal side. The lateral eyes of this

specimen are only faintly apparent. The marginal rim of the carapace in both paratypes is particularly well preserved.

The prosoma is broad, evenly rounded at the anterior lateral angles and the anterior margin. Base straight, forming an approximate right angle with the lateral margin. Lateral and anterior margins bounded by a thin, rounded, raised rim which gradually disappears toward the genal angles (see text figures 1a and 1b).

Lateral eyes, reniform, intramarginal, located anteriorly on the carapace in front of the ocelli, which occupy a nearly central position. The eyes of the uncrushed holotype are 3.0 mm. long, 1.3 mm. wide, are located on the carapace, 5.4 mm. from the base, 2.0 mm. from the lateral margin, 2.5 mm. from the anterior margin, and are 6.0 mm. apart at their anterior ends and 7.5 mm. apart posteriorly. The lateral eyes of the figured paratype are mostly too distorted for accurate measurement, but the right eye is 3.5 mm. in length. Facets are not apparent.

Ornamentation of the carapace consists of distinct transverse striations along the anterior part in front of the eyes. The remainder of the carapace appears to be smooth.

The holotype measures 14.6 mm. in width across the base of the eyes, and 16.8 mm. at the base. This carapace is broken, but is 11.2 mm. long, and is estimated to have had a complete length of 12.5 mm. The length-width ratio is about 7.4:10. The figured paratype is 9.8 mm. long, 15.6 mm. across the base of the eyes, and 17.4 mm. at the base. The unfigured carapace is 9.5 mm. long and is estimated to have been 13 mm. wide at the base.

Two fragments of the mesosoma are known. One of these is part of an abdominal plate which clearly shows the transverse lines much like those on the carapace. The other fragment is part of a tergite which is bandlike, rounded at the anterior-lateral margins, and forms a right angle at the posterior epimeral angle. It is marked with transverse lines.

These fragments indicate an overall length of about 70 mm. If this is the greatest size of the species, it is considerably smaller than most others of the genus.

Horizon and locality.—Occurs in shales and thin waterlime layers in the upper part of the Silurian Cayugan Wills Creek formation on the east side of Elkhorn Mountain, one-third mile northwest, along a narrow road, of the church at Bass, Hardy County, West Virginia. Associated with *Eurypterus* sp., *Pterygotus* sp., *Lingula*, and marine ostracods. The eurypterids at this locality are fragmentary, and probably were derived from a fresh water source. Ripple marks and mud cracks are common in the rock.

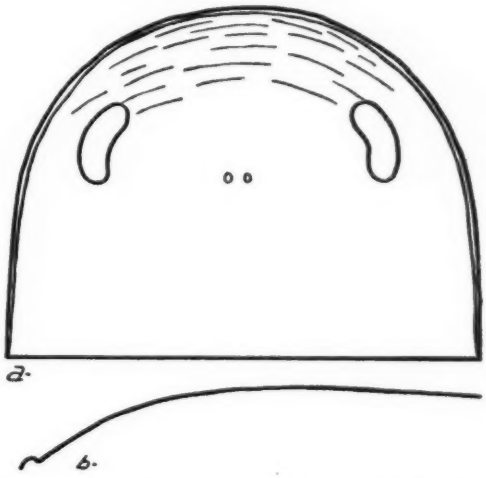

FIG. 1—*Hughmilleria bellistriata* Kjellesvig-Waering. (a), Restoration of prosoma; (b), lateral aspect of prosoma.

Repository.—All specimens have been deposited in the U. S. National Museum, Washington, D.C.

Remarks.—*Hughmilleria bellistriata* is considerably different from other North American species of this genus. The distinctly oval anterior margin, the transverse linear sculpturing on the anterior part of the carapace, the intramarginal eyes, and apparent small size of the species, form the main specific characteristics. *Hughmilleria shawangunk* Clarke of the Shawangunk grit of New York and Pennsylvania has intramarginal eyes like *H. bellistriata*, but the carapace has an altogether different outline, being acute rather than rounded as in the latter. The genotype *H. socialis* Sarle has marginal eyes and an acute carapace which serve to separate it from the above described form.

A small distorted carapace from the Wills Creek formation on Wills Creek, Cumberland, Maryland was described by C. K. Swartz (1923, pp. 716–717, pl. LXVI, fig. 2) as *Hughmilleria sp. cf. shawangunk*. This form has intramarginal eyes like *H. bellistriata* but, unfortunately, it is distorted and gives the appearance of bring considerably more elongated and narrower than *H. bellistriata*. Both forms occur in the same formation but were found at localities approximately fifty miles appart. The position of the eyes and the small size suggests that they are conspecific.

A complete list of the eurypterids which, in this writer's opinion, belong to the genus *Hughmilleria* is as follows (in alphabetical order):

Hughmilleria banksi (Salter)	Silurian	England
bellistriata Kjellesvig-Waering	Silurian	West Virginia, Maryland (?)
conicus (Laurie)	Silurian	Scotland
kilfoylei Ruedemann	Ordovician	New York
lanceolata (Salter)	Silurian	Scotland
(?) *lata* Størmer	Silurian	Norway
(?) *linearis* (Salter)	Silurian	England
magna Clarke and Ruedemann	Ordovician	New York
(?) *maria* Clarke	Silurian	New York
norvegica (Kiær)	Silurian	Norway
patteni Størmer	Silurian	Saaremaa
phelpsae Ruedemann	Silurian	New York
prisca Ruedemann	Ordovician	New York
(?) *prominens* Hall	Silurian	New York
(?) *pygmaea* (Salter)	Silurian & Devonian	England, Germany
shawangunk Clarke	Silurian	New York, Pennsylvania
socialis Sarle	Silurian	New York
socialis Sarle *robusta* Sarle	Silurian	New York
sp. Hundt	Silurian	Germany
sp. Størmer	Silurian	Hitra, Norway
trigona (Ruedemann)	Silurian	New York
uticana Ruedemann	Ordovician	New York

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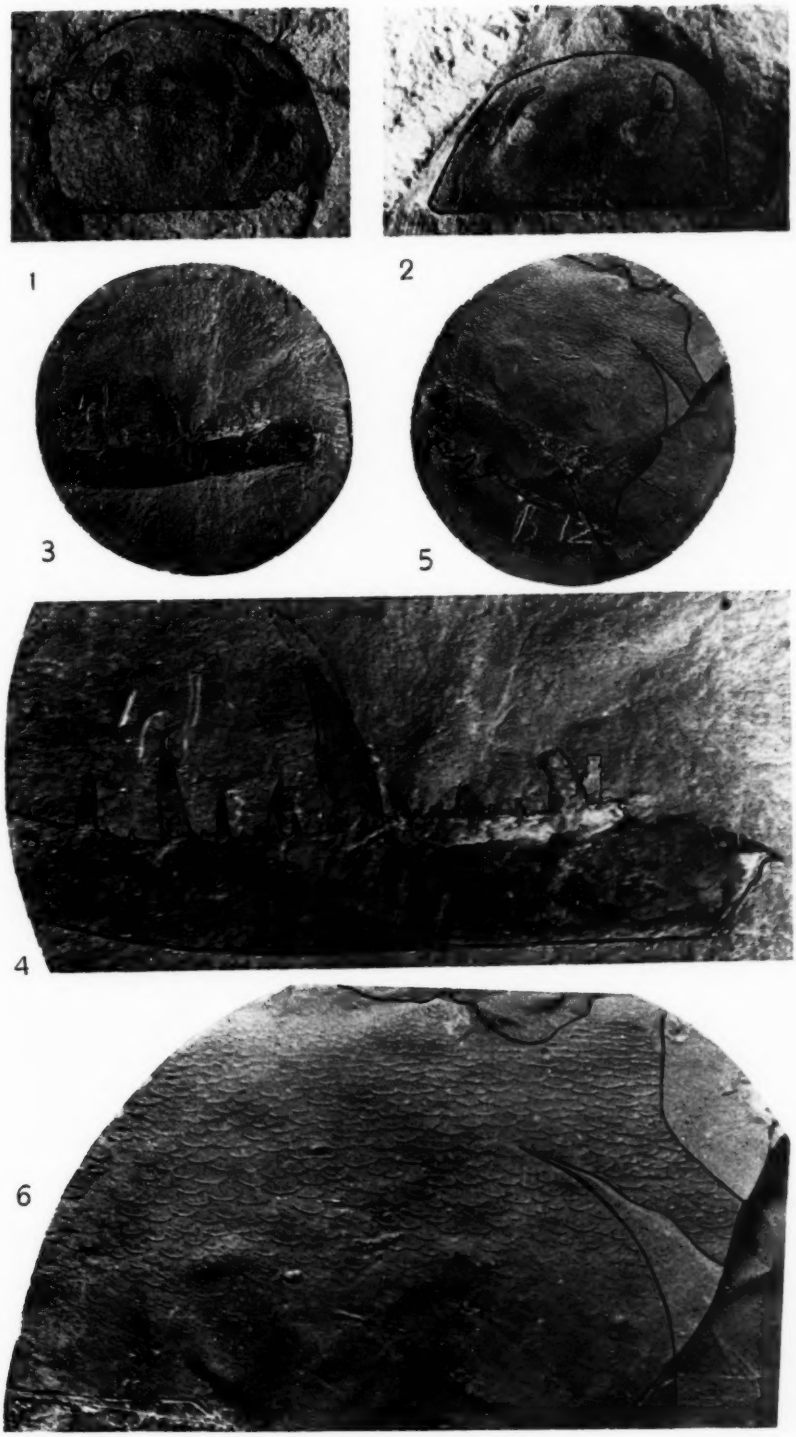
TILTON, JOHN L., PROUTY, W. F., TUCKER, R. C., and PRICE, PAUL H., 1927, Hampshire and Hardy Counties: West Virginia Geol. Survey

EXPLANATION OF PLATE 38

FIGS. *1, 2*—*Hughmilleria bellistriata* Kjellesvig-Waering, n. sp., from the Silurian Wills Creek shale near Bass, Hardy County, West Virginia. *1*, Holotype, ×2.5; *2*, distorted prosoma, ×2.3. (p. 226)

3–6—*Pterygotus floridanus* Kjellesvig-Waering, n. sp., from the Upper Silurian, Suwannee County, Florida. *3*, Core of shale with holotype, a fixed ramus, ×0.6; *4*, enlargement of same showing details of the dentition, ×1.8. *5*, Paratype, part of an abdominal plate, ×0.6; *6*, enlargement of same showing details of ornamentation, ×1.8. (p. 229)



Kjellesvig-Waering, Silurian eurypterids

JOURNAL OF PALEONTOLOGY, VOL. 24, NO. 2, PP. 229–231, MARCH 1950

A NEW SILURIAN EURYPTERID FROM FLORIDA

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ABSTRACT—Fragments of the fixed ramus and abdominal segments of a large eurypterid were encountered in Silurian shales in a core taken at 3552–3568 feet from a well in Suwannee County, Florida. The species, here named *Pterygotus floridanus*, represents the southernmost record of Eurypterida in North America.

RECORDS of Eurypterida in North America are restricted to the northern half of the continent. Specimens have been reported from Labrador, the Maritime Provinces, Quebec, Ontario, Maine, New York, Pennsylvania, Ohio, Indiana, Illinois, Wyoming, Montana, Nebraska, Kansas, Oklahoma, West Virginia, Maryland and Virginia. However, by far the greatest number of specimens came from New York state.

The southernmost occurrences in this continent have been reported by Shuler (1915, p. 551), Swartz (1923, p. 716), Tilton (1927, p. 262) and Kjellesvig-Waering (see preceding article), who described several Silurian forms, mainly fragmentary, from Virginia, Maryland and West Virginia. From the middle Permian of northern Oklahoma, Decker (1938, p. 396) described *Eurypterus oklahomensis*, now considered by Kjellesvig-Waering (1948, p. 41) to be *Lepidoderma sellardsi* (Dunbar).

An unusual occurrence of Eurypterida in subsurface strata of northern Florida was revealed to the writer by G. Arthur Cooper, who also kindly made available the specimens here described. These are of considerable interest inasmuch as the discovery extends the distribution of eurypterids in North America southward by more than five hundred miles. The fragments, consisting of a well preserved fixed ramus of the chelicera, and several large fragments of the abdominal plates and tergites, represent a new *Pterygotus*, here named *P. floridanus*, which undoubtedly exceeded four feet in total length. The specimens were recovered in cores of Upper Silurian shale encountered in a test well drilled by the Sun Oil Company in Suwannee County, Florida.

The writer is particularly indebted to G. Arthur Cooper, Curator of Invertebrate Paleontology and Paleobotany, U. S. National Museum, for loan of the specimens. He also wishes to thank Louise Jordan, paleontologist of the Sun Oil Company, Tallahassee, Florida, who kindly contributed data and correlations of the strata encountered in the test well. The Sun Oil Company released the cores of their well to the U. S. National Museum.

Class MEROSTOMATA (Dana) Woodward
Order EURYPTERIDA Burmeister
Family PTERYGOTIDAE
Clarke and Ruedemann
Genus PTERYGOTUS Agassiz 1839
PTERYGOTUS FLORIDANUS
Kjellesvig-Waering, n. sp.
Plate 38, figures 3–6

This species is based on the fixed ramus of the chelicera, considered the holotype of the species, and fragments of tergites and abdominal plates all belonging to an eurypterid of considerable dimensions. The greater portion of the fixed ramus is preserved, as attested to by the presence of 16 teeth. The distal end, possibly 2 cm. in length, was destroyed by the action of the core bit. The extreme base, adjoining the area of articulation with the free ramus, is likewise missing.

The main body of the fixed ramus is relatively slender, definitely convex on the outer margin and concave on the inner edge, which is armed with numerous sharp teeth. It measures 62.0 mm. in total length and is 11.0 mm. wide near the base, or place of attachment of the free ramus, but gradually narrows to 9.0 mm. in the midsection, and finally to 7.5 mm. at the distal end of the part preserved. The writer estimates, by comparison with the ramus of *Pterygotus cobbi*, that the complete ramus of the

Florida specimen was 90 mm. in length. No ornamentation occurs on its body.

The teeth in general are of four distinct sizes. A long stout tooth, considerably larger than any other, occurs in the central part of the ramus and constitutes one of the main specific characteristics of this species. This tooth rises at approximately a right angle, but the distal end, which is partly broken, curves slightly forward. The base of this tooth is 4 mm. wide and tapers gradually toward the curved distal end. The preserved part is 14 mm. long, but the complete tooth probably measured nearly 20 mm. in total length.

There is another large tooth near the posterior end of the ramus. It is mostly broken away but is 3.5 mm. wide at the base.

The next largest teeth occur on both sides of the large central tooth. These extend nearly at right angles to the ramus but are inclined slightly forward. All are less than half as large as the central tooth. The foremost of this series measures 8.0 mm. in length and 2.5 mm. in width at the base.

The third series of teeth occurs between the ones above described and all are less than 5 mm. in length.

The smallest teeth are short, stout, but sharply pointed, and rise nearly at right angles from the ramus. All are less than 1.5 mm. in length. No teeth are present on the distal part of the incomplete ramus, at least for a distance of 6.5 mm. from the most anteriorly located tooth.

All teeth are striated with fine grooves.

Three irregular patches of tergites or abdominal plates were recovered in the core. All have the same distinct ornamentation, and it is assumed that they belong to the same species as the associated fixed ramus. Only one of these patches is worthy of description. This fragment, apparently a small part of an abdominal plate, is about 6 cm. long by 5 cm. wide. The ornamentation is perfectly preserved. At the anterior edge of the plate a rather narrow band is marked by small semilunar typical *Pterygotus* scales not exceeding 0.5 mm. in width. The ornamentation abruptly changes and a band about 3 cm. wide is occupied by larger flattened scales 1.0 mm. to 2.0 mm. in width. In general, each of the scale-like structures is a low elevation on the integument in the form of a slightly bent ridge having its apex directed posteriorly. In between the coarse scales are very fine semilunar scales differing from one another in size, although none are more than one-tenth to one-twentieth the size of the coarse flattened scales. The zone of coarse scales gradually fades out backward, so that the posterior part of the plate is quite smooth.

Pterygotus floridanus undoubtedly reached gigantic proportions. Clarke and Ruedemann (1912, p. 374) estimate that *P. cobbi*, with a free ramus of 13 cm., had an overall length of slightly over 2 meters, or 6 feet, 7 inches. These proportions are taken from complete specimens of other *Pterygoti*. *P. floridanus*, having an estimated length of the fixed ramus of 9 cm., probably measured about 1.4 meters or 4 feet, 7 inches in total length. The portion of the large abdominal plate likewise suggests a form of similar proportions.

P. floridanus is similar in general characteristics to *P. cobbi* Hall of the Silurian Bertie waterlime of western New York and *P. barrandei* Semper of the Upper Silurian of Bohemia. It differs from *P. cobbi*, however, in the greater development of the central tooth and there are minor differences in the arrangement of the lesser teeth of the free ramus. It differs similarly from *P. barrandei*, and also seems to have had a more slender fixed ramus.

Repository.—The specimens described above are in the collections of the U. S. National Museum, Washington, D. C.

Horizon and locality.—The eurypterid fragments are from a core taken in the Sun Oil Company's No. 1 J. H. Tillis well, C-SE$\frac{1}{4}$-SW$\frac{1}{4}$, sec. 28, T 2 S, R 15 E, Suwannee County, Florida. This well was commenced on August 7, 1947, and was abandoned as a dry hole on September 1, 1947, at a total depth of 3571 feet.

Louise Jordan (personal communication, December 13, 1948), who examined the sample cuttings and cores, reports the following strata penetrated:

Spudded in Miocene sands	
100–110 feet:	Top Oligocene (by cuttings)
190–200 feet:	Top Ocala (Eocene) (by cuttings)
1772 feet	Top Cretaceous (by electric log)
3332 feet:	Top Lower Cretaceous (by electric log)
3490 feet:	Top Paleozoic (by electric log)

Sixteen feet of core was recovered between 3552–3568 feet, which consisted of soft black shale with eurypterid fragments, *Tentaculites* and fragments of thin-shelled pelecypods. Jordan reports that similar weathered material was cored between 3494–3502 feet. Paleozoic strata 81 feet thick were penetrated immediately beneath Lower Cretaceous conglomerate.

The Paleozoic cores were sent to G. Arthur Cooper, who identified the shale as Upper Silurian on the basis of the eurypterid and molluscan fossils. The writer agrees with this correlation because of the obvious similarity of *P. floridanus* to the Upper Silurian *P. cobbi* and *P. barrandei*.

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CARBONIFEROUS PLANT SPORES FROM DAGGETT COUNTY, UTAH

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ABSTRACT—Post-Madison, pre-Belden plant spores from Daggett County, Utah, are described and illustrated. The assemblage is compared to British, Polish, and Russian assemblages of similar age. Two new genera are proposed, *Rotaspora* and *Tripartites*.

RECENT studies of plant spores of Pennsylvanian coals of the United States have provided useful information concerning the distribution of genera and species and have indicated that these microfossils are of value in the correlation of coal beds. Kosanke (1947), working with Illinois coals, and Cross (1947), working with West Virginia and Kentucky coals, have strongly suggested that plant spores may be used in both regional and interregional correlations. Pennsylvanian microfloral zones are apparently now in the process of being defined with some precision for this purpose.

Numerous coal and carbonaceous shale beds of Mississippian age are present in the United States, but the study of plant spores from these beds has been neglected. The purpose of this paper is to record a spore assemblage of probable Mississippian age which contains spore types not previously described from the United States. Similarities between these microfossils and those reported from British, Polish, and Russian localities probably indicate similarity of the widely separated floras. If this conclusion is accepted we shall have reason to regard this type of plant microfossil as much more significant geologically for long range correlations than has been generally recognized. In any event, these spore forms suggest a more diversified Carboniferous flora in Utah than there was evidence of before.

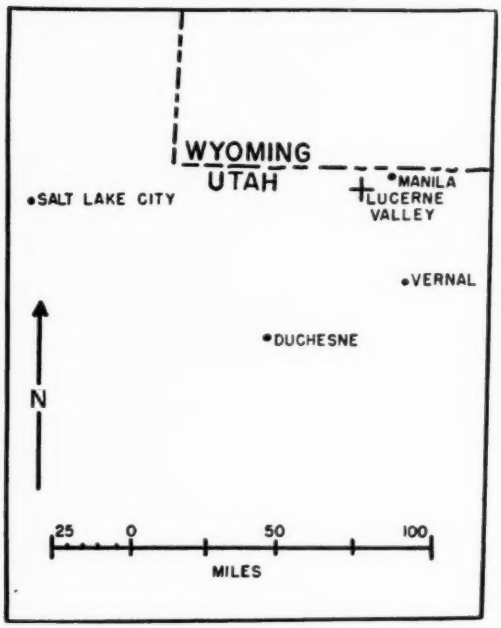


FIG. 1—Outline map showing the location of Lucerne Valley.

Mr. P. M. McMinn, a graduate student at the University of Wisconsin, furnished the coal sample from which the plant microfossils were obtained. Most of the work for the present paper was completed while I was a graduate student at the University of Wisconsin in 1948. I am indebted to R.M. Kosanke, of the Illinois Geological Survey, and to J. M. Schopf, of the United States Geological Survey, for reading my manuscript and giving valuable advice and criticism. All type and illustrated specimens are deposited at the Missouri Geological Survey, Rolla, Missouri.

COLLECTING LOCALITY AND STRATIGRAPHY

The coal sample from which the plant microfossils were obtained was collected by Mr. P. M. McMinn in the summer of 1947. The sample was taken from a digging located in the NE cor., SW¼ sec. 11, T. 2 N., R. 18 E., Daggett County, Utah (fig. 1).

This locality is on the west side of Lucerne Valley approximately four miles west of Thompson's (1945) Sheep Mountain Canyon locality.

Information concerning the stratigraphy of this locality was obtained by personal communication with Mr. P. M. McMinn and from his unpublished Master's thesis. The coal bed is approximately two feet thick and lies near the base of a shale section approximately 20 feet thick. The top and bottom contacts of this shale are obscured by cover. The coal bed lies approximately 190 feet below the base of the Belden formation, which is about 500 feet thick at this locality, and approximately 550 feet above the top of the Madison formation, which has about 300 feet of exposed thickness. No detailed correlation can be made for the beds between the Madison and Belden formations at this locality at the present time.

The Belden formation is correlated with the type Morrow of Arkansas by Thompson (1945). The Madison formation is considered late Kinderhookian and Osagean in age, but as noted by Weller *et al.* (1948), no satisfactory detailed correlation with the Mississippi Valley section is possible at this time. Stratigraphic evidence indicates that the Daggett County coal is Meramecian, Chesterian, or Springeran in age.

HISTORICAL REVIEW

Very few papers have been published concerning spores of comparable age. The following papers seem most pertinent for comparison with the microfossil assemblage reported here from Daggett County. Reinsch (1884) described spores and other microfossils from coals of Russia and Saxony. Precise information concerning the geologic occurrence of many of his forms is lacking, but Reinsch's work is nevertheless valuable for comparative purposes. Berry (1937) described fourteen species of small spores from the "Pennington coal" of Rhea County, Tennessee. This coal was considered upper Chesterian in age, although the exact horizon of the bed from which the assemblage was obtained is unknown. Zerndt (1937) described megaspores from the coals of the Marginal group of the Polish coal basin. Raistrick (1938) described small spores from coals between the Cementstone series and the Millstone Grit of Northumberland. Luber and Waltz (1938) have included a considerable number of small spores from coals of Tournaisian and Visean, as well as Westphalian, age in several coal basins of the U.S.S.R. Knox (1947) reported on small spores from coals of the Limestone Coal group of Scotland.

COMPOSITION OF THE ASSEMBLAGE

The spore assemblage from Daggett County, Utah, contains representatives of eight genera that have been established for isolated plant spores. Two new genera are proposed for forms that appear to be excluded from previously described genera. Two other forms are described but not assigned because insufficient material is at hand to warrant it. A number of forms are withheld for further study, but these are somewhat generalized and their omission does not affect the general aspect of the assemblage.

Previously described genera recorded are: *Triletes*, *Punctati-sporites*, *Granulati-sporites*, *Laevigato-sporites*, *Denso-sporites*, *Endosporites*, *Lycospora* and *Calamospora*. Representatives of these genera have been described from Carboniferous coals of other areas, although usually not under the present classification. Two new genera, *Rotaspora* and *Tripartites*, are proposed for forms from the Daggett County assemblage. As noted in the specific descriptions, these genera may include several forms described under non-taxonomic systems from Mississippian coals of other areas.

A statistical analysis of the small spores of the assemblage indicates the relative abundance of specimens assigned to the dominant genera. The following figures are taken from data compiled in the examination of all specimens (4,146) present on six slides chosen at random from the collection.

Denso-sporites	92.3%
Tripartites, n. gen.	2.2%
Punctati-sporites	1.8%
Granulati-sporites	1.5%
Rotaspora, n. gen.	1.4%
Others	0.8%

The great abundance of *Denso-sporites* spores indicates that their parent plants had a great numerical superiority to the

other plants or their parent plants produced relatively more spores than the others. Unfortunately, spores of the *Denso-sporites* type have not been recognized in connection with fructifications and thus their affinity is unknown. Schopf, Wilson, and Bentall (1944) discussed the affinities of the various spore genera and from their conclusions the general nature of the flora represented by the assemblage may be postulated. It is probable that the vegetation which made up the coal bed included filicineans, calamarians, cordaitaleans, pteridosperms, and lycopsids.

COMPARISON OF MISSISSIPPIAN SPORE ASSEMBLAGES

It is difficult to compare the Mississippian spore assemblages on a generic and specific basis, as each investigator has used a different method of classification. Reinsch (1884) used a rather complex numerical system for designating various forms and their relationships and grouped most of his types under *Trileteae*. Berry (1937) and Zerndt (1937) used binomial systems of classification and their genera and species have been discussed and evaluated by Schopf, Wilson, and Bentall (1944). Raistrick (1938) used an alphabetical-numerical system devised by Raistrick and Simpson (1933) which can only be approximately identified with the Schopf, Wilson, and Bentall (1944) generic groups. Knox (1947) used Raistrick and Simpson's (1933) system in part and in part a numerical system of her own. While the individual spores described under these non-taxonomic systems often can be assigned to spore genera with some certainty, specific determinations are usually hazardous. Luber and Waltz (1938) used a binomial system based upon Ibrahim's (1933) system. Their paper was not available to Schopf, Wilson, and Bentall (1944) for consideration in their synopsis.

Certain characteristics, however, may be noted which are common to the Mississippian spore assemblages described in the papers listed above and the assemblage obtained from Daggett County. There is usually a low percentage or complete absence of small spores of the *Laevigato-sporites* type. Raistrick (1938) is the only author who noted their occurrence in Mississippian coals. Kosanke (1947) did not record their occurrence below the Reynoldsburg coal bed (Caseyville) in Illinois. Mississippian assemblages usually include a high percentage of small spores of the *Denso-sporites* and similar types with the coat greatly thickened at the equator. Small spores of the *Punctati-sporites*, *Reticulati-sporites*, *Triquitrites*, *Reinschospora*, and *Raistrickia* types vary greatly in abundance from complete absence to sub-dominance. There is usually a low abundance or complete absence of small spores of the *Lyco-spora*, *Calamospora*, *Endosporites*, and *Cir-ratriradites* types. Many of the small spores treated under non-taxonomic systems have been inadequately described and for this reason some question arises regarding their alliance with established genera.

It is extremely hazardous to attempt to establish conspecific identity between the spores investigated and those described in the literature. The majority of the species which have been described are established with inadequate descriptions and illustrations and it will be necessary to examine the type specimens before the present confusion regarding the nomenclature is resolved. At this stage of knowledge I hesitate to make conspecific identifications with material from distant sources unless the structures appear quite specialized, as in *Triletes agnina* (Zerndt) Schopf, Wilson, and Bentall, 1944. This species, and others by Zerndt, were described in minute detail and illustrated by excellent photomicrographs. The greater portion of spores have been described in a cursory manner and illustrated by line drawings. In view of these difficulties, those forms which, in my opinion, could possibly be conspecific with established species are mentioned comparatively. Later studies should show whether they are the same or should be described as new species. These forms are, for the most part, highly generalized, and probably will be of lesser stratigraphic significance unless they are abundant enough to be interpreted ecologically.

Triletes agnina (Zerndt) Schopf, Wilson, and Bentall, 1944, and *Triletes radiosus* Schopf, Wilson, and Bentall, 1944, were described by Zerndt (1937) from coals of the Marginal group (Namurian) of the Polish

coal basin. These two species are not recognized from the Anticlinal group (Zerndt, 1934, 1937) which thus fixes the upper limit of these species in Poland. Spores which are apparently congeneric to *Tripartites*, n. gen., have a somewhat restricted range according to several authors. Raistrick (1938) noted the occurrence of this type of spore only in the Shilbottle coal bed of the middle Limestone group in his investigation of coals from the Cementstone series to the upper Limestone group in Northumberland. Knox (1947) noted its occurrence in coals of the Limestone Coal group in Scotland and stated that it had not been found in the Productive Coal Measures. Luber and Waltz (1937) described this type of spore from Tournaisian-Viséan coals but did not note its occurrence in the Westphalian coals of the U.S.S.R. This type of spore is apparently restricted to pre-Namurian coal beds in Great Britian and Russia.

Further work may indicate that other forms present in the Daggett County coal bed are of more value in specific correlations, but at present the chief reliance must be placed on the forms discussed above and the general features of spore morphology. The small spore assemblage most closely resembles those described from Great Britian and Russia of Viséan age, but the bizarrely ornamented forms described from Tournaisian coals of Russia are not represented. From this very meager evidence, it is concluded that the Daggett County coal bed is probably Chesterian or Springeran in age. The assemblage described by Berry (1937) does not include forms which can be considered diagnostic at the present time.

SYSTEMATIC DESCRIPTIONS

Genus TRILETES (Reinsch) Schopf

Triletes REINSCH, 1881, Neue Unterschungen Über d. Mikrostruktur der Steinkohle, pl. 11, figs. 1–10, 15, 16.—emend. SCHOPF, 1938, Illinois Geol. Survey Rept. Inv. 50, pp. 17–18.

Genotype.—Triletes reinschi (Ibrahim) Schopf, by designation of Schopf, 1938, p. 18

TRILETES AGNINA (Zerndt) Schopf, Wilson and Bentall
Plate 39, figures 1, 2

Lagenicula agnina ZERNDT, 1937, Acad. polonaise sci. Trav. Geol. no. 3, p. 14, pls. 21–22.

Triletes agnina (ZERNDT), SCHOPF, WILSON and BENTALL, 1944, Illinois Geol. Survey Rept. Inv. 91, p. 20.

Description.—Spores trilete, radial; circular to subcircular in transverse plane; diameter 816 to 1360 microns; surface of spore coarsely rugose, verrucose, protuberances approximately 18 microns high, 20 to 50 microns in diameter, and irregular in outline; apical portions of pyramic segments moderately elongated, much thickened, and upraised apical portions demarcated as a vestibule; coarser tubercules appear opposite terminations of the trilete rays; trilete rays rather short, extend one-third to one-fourth the diameter of the compressed spore.

Occurrence.—Coals of the Marginal group of the Polish coal basin; post-Madison, pre-Belden coal of Daggett County, Utah.

TRILETES cf. T. RADIOSUS Schopf, Wilson and Bentall[1]
Plate 39, figures 3, 4

Triletes radiatus ZERNDT, 1937, Acad. polonaise sci. Trav. Geol. no. 3, p. 10, fig. 7, pl. 13, figs. 1–15.

Triletes radiosus SCHOPF, WILSON and BENTALL, 1944, Illinois Geol. Survey Rept. Inv. 91, p. 62.

Description.—Spore trilete, radial; circular to subcircular in transverse plane; diameter 500 to 800 microns; surface of spore granulose to minutely tuberculate; equatorial flange composed of flat filaments, simple or one or more times divided, apparently not fused at extremities; trilete rays extend to equatorial flange, lips elevated approximately 50 microns and plicated throughout their length.

Remarks.—Zerndt's original description and illustrations of *Triletes radiosus* indicate that the interradial areas of the spore body are coarsely tuberculate, which is at variance with the single specimen observed in my collection. Because only a single specimen has been found, it has been impossible to adequately describe a new species, if such a treatment is warranted. Since its status is in doubt, the specimen from Daggett County, Utah, is questionably assigned to

[1] *Triletes radiatus* Zerndt, 1937, is a later homonym conflicting with *Sporonites radiatus* Ibrahim, 1932, when the later was transferred to *Triletes* by Schopf, Wilson, and Bentall, 1944, as they reported in a note on page 24. They proposed the new name indicated above.

Triletes radiosus Schopf, Wilson, and Bentall, 1944.

Occurrence.—Coals of the Marginal group of the Polish coal basin; post-Madison, pre-Belden coal of Daggett County, Utah.

Genus PUNCTATI-SPORITES (Ibrahim) Schopf, Wilson and Bentall

Punctati-sporites, IBRAHIM, 1933, Sporenformen des Aegirhorizonts, p. 21.—emend. SCHOPF, WILSON and BENTALL, 1944, Illinois Geol. Survey Rept. Inv. 91, pp. 29–32.

Genotype.—Punctati-sporites punctatus (Ibrahim) Ibrahim, by designation of Ibrahim, 1933, p. 21.

PUNCTATI-SPORITES UTAHENSIS Schemel, n. sp. Plate 39, figure 6

Description.—Spores trilete, radial; circular to subcircular in transverse plane; diameter 45 to 75 microns; surface of spore rather coarsely punctate; trilete rays 15 to 21 microns long, one ray usually about 4 microns longer than other two, lips not developed in usual manner, but as tapering swells broadening away from point of intersection of trilete rays.

Remarks.—The holotype is the only specimen observed with good proximo-distal orientation. The photograph shows the specimen in optical section, as do all other photographs of the small spores.

Occurrence.—Post-Madison, pre-Belden coal of Daggett County, Utah.

PUNCTATI-SPORITES sp. A Plate 39, figure 5

Description.—Spores trilete, radial; subtriangular in transverse plane, corners rounded, sides slightly to strongly convex; diameter 55 to 60 microns; surface of spore laevigate; pyramic areas slightly granulose and slightly thicker than remainder of spore wall, apical portions of pyramic segments slightly upraised; trilete rays two-thirds the length of the radius, lips not modified.

Remarks.—This species is represented by two specimens observed in my collection. The photograph is rather poor in that sufficient depth could not be obtained to illustrate clearly the upraised pyramic segments and the body proper. The suture of the specimen is actually closed. The thickened pyramic area is rather unusual for spores of the *Punctati-sporites* type. This species resembles *Punctati-sporites sphaerotriangulatus* (Loose) Schopf, Wilson, and Bentall, 1944, in size, shape, and trilete suture, but the latter species apparently does not have a thickened pyramic area.

Occurrence.—Post-Madison, pre-Belden coal of Daggett County, Utah.

PUNCTATI-SPORITES sp. B Plate 39, figure 7

Description.—Spore trilete, radial; circular in transverse plane; diameter approximately 55 microns; surface of spore laevigate; trilete rays extend to within 4 microns of the equator; lips not modified.

Remarks.—This species is represented by a single specimen observed in my collection. The extreme length of the trilete rays is rather unusual in comparison with other described species of this genus, but the genotype, *Punctati-sporites punctatus* (Ibrahim) Ibrahim, 1933, has trilete rays with the same general length relationship to the diameter of the spore body.

Occurrence.—Post-Madison, pre-Belden coal of Daggett County, Utah.

PUNCTATI-SPORITES sp. C Plate 39, figure 8

Description.—Spore trilete, radial; circular in transverse plane; diameter approximately 65 microns; surface of spore laevigate to minutely punctate; trilete rays approximately 18 microns long; trilete lips well developed, approximately 2 microns wide and flaring away from suture at extremities.

Occurrence.—Post-Madison, pre-Belden coal of Daggett County, Utah.

PUNCTATI-SPORITES sp. D Plate 39, figure 9

Description.—Spore trilete, radial; circular in transverse plane; diameter approximately 55 microns; surface of spore laevigate to minutely punctate; trilete rays approximately 15 microns long; trilete lips not modified.

Occurrence.—Post-Madison, pre-Belden coal of Daggett County, Utah.

PUNCTATI-SPORITES sp. E
Plate 39, figure 10

Description.—Spore trilete (?), radial; circular in transverse plane; diameter approximately 56 microns; surface of spore coarsely reticulate, lumina very irregular in outline, approximately 4 by 6 microns in size, muri approximately 2 microns wide, do not thicken at junction points; trilete rays not observed.

Remarks.—This species is represented by a single specimen observed in my collection. *Punctati-sporites* sp. D appears to be related, at least in part, to spores assigned to Raistrick and Simpson's (1933, p. 228, fig. 1) group F by Raistrick and Simpson (1933) and Raistrick (1934). This species is also similar to forms illustrated by Knox (1939, figs. 48, 49) in her comparison of Carboniferous spores to spores of living mosses. This species may be related to *Zonala-sporites taciturnus* (Loose) Loose, 1934, which was set in *incertae sedis* by Schopf, Wilson, and Bentall, 1944. Loose's description and drawings are, however, somewhat difficult to interpret. The reference of my specimen to *Punctati-sporites* may be questioned because of the nature of its reticulation. The lack of material hinders any other treatment of this specimen at this time.

Occurrence.—Post-Madison, pre-Belden coal of Daggett County, Utah.

Genus GRANULATI-SPORITES
(Ibrahim) Schopf, Wilson
and Bentall

Granulati-sporites IBRAHIM, 1933, Sporenformen des Aegirhorizonts, p. 21.—emend. SCHOPF, WILSON and BENTALL, 1944, Illinois Geol. Survey Rept. Inv. 91, pp. 32–33.

Genotype.—Granulati-sporites granulatus Ibrahim, by designation of Ibrahim, 1933, p. 21

GRANULATI-SPORITES cf.
G. GRANULATUS Ibrahim
Plate 39, figure 14

Granulati-sporites granulatus IBRAHIM, 1933, Sporenformen des Aegirhorizonts, p. 22, pl. 6, fig. 51.

Description.—Spores trilete, radial; triangular in transverse plane; diameter 25 to 35 microns; surface of spore finely granulose to weakly punctate; trilete rays approximately two-thirds the length of the radius, lips not modified.

Remarks.—Cross (1947, pl. V, fig. 172) illustrated a specimen measuring 20 by 24 microns that he termed *Granulati-sporites granulatus* Ibrahim, 1933. I believe that this specimen is different enough from the type of *G. granulatus* that it should be assigned to some other species. The form Cross illustrated possesses a distinct spinose, not granulose, ornamentation. Ibrahim's original description states: "Oberfläche fein granuliert bis punktiert," and his illustration indicates weak granulation. Cross's illustrated specimen and my specimens, in any event, do not appear to be conspecific.

Occurrence.—Coals of the Westphalian B zone of the Ruhr district of Western Germany; post-Madison, pre-Belden coal of Daggett County, Utah.

GRANULATI-SPORITES cf.
G. MICROSAETOSUS
(Loose) Schopf, Wilson
and Bentall
Plate 39, figure 11

Sporonites microsaetosus LOOSE, 1932, Neues Jahrb., Beilage-Band 67, Abt. B, p. 450, pl. 18, fig. 40.

Setosi-sporites microsaetosus (LOOSE) IBRAHIM, 1933, Sporenformen des Aegirhorizonts, p. 26. —LOOSE, 1934, Inst. Paläobot. Arb., vol. 4, no. 3. p. 148.

Granulati-sporites microsaetosus (LOOSE) SCHOPF, WILSON and BENTALL, 1944, Illinois Geol. Surv. Rept. Inv. 91, p. 33.

Description.—Spores trilete, radial; subtriangular in transverse plane, corners rounded, sides slightly convex to slightly concave; diameter 30 to 40 microns; surface of spore saetose to spinose, spines 2 to 3 microns long, 2 to 3 microns wide at the base, equilateral in outline; trilete rays two-thirds the length of the radius, lips not modified.

Remarks.—Luber and Waltz (1938) describe a form from the Karaganda basin which they consider conspecific to *Apiculati-sporites microspinosus* Ibrahim. Their description and illustration (p. 24, pl. 5, fig. 64) lead me to believe that their form is conspecific with *Granulati-sporites microsaetosus.*

Occurrence.—Coals of the Westphalian B zone of the Ruhr district of Western Ger-

many; post-Madison, pre-Belden coal of Daggett County, Utah.

GRANULATI-SPORITES INFLATUS
Schemel, n. sp.
Plate 39, figure 13

Description.—Spores trilete, radial; deltoid in transverse plane, corners broadly rounded, sides slightly to strongly convex; diameter 30 to 47 microns; surface of spore laevigate; trilete rays approximately three-quarters the length of the radius, lips not modified.

Remarks.—The holotype illustrates the average convexity of the sides. This species closely resembles *Deltoidospora cascadensis* Miner, 1935, from Lower Cretaceous coals of Montana, and *Sporonites neddeni* Potonié 1931, from Tertiary brown coals of Germany. The great difference in age of these species makes it unlikely that they belonged to the same species of parent plants. Furthermore, work by Loose, Ibrahim, Wilson, and others on Middle and Upper Pennsylvanian coals has not revealed small spores of this type. This is a generalized form which has characteristics common to both *Granulati-sporites* and *Punctati-sporites*. It is placed in *Granulati-sporites* because of its small size.

Occurrence.—Post-Madison, pre-Belden coal of Daggett County, Utah.

GRANULATI-SPORITES sp. A
Plate 39, figure 12

Description.—Spore trilete, radial; deltoid in transverse plane, corners rounded, sides straight to moderately concave; diameter 42 to 53 microns; surface of spore moderately punctate, toward the apex pyramic areas lack ornamentation; trilete rays approximately 15 microns long, lips not modified.

Remarks.—This species is represented by a single specimen observed in my collection. I am not aware of any previously described or illustrated spore which closely resembles this form.

Occurrence.—Post-Madison, pre-Belden coal of Daggett County, Utah.

GRANULATI-SPORITES sp. B
Plate 39, figure 15

Description.—Spore trilete, radial; subtriangular in transverse plane, corners rounded, sides moderately concave; diameter approximately 40 microns; pyramic areas slightly flattened for a distance of approximately 6 microns on both sides of individual trilete rays; surface of spore laevigate to minutely punctate; trilete rays approximately 15 microns long; lips not modified.

Remarks.—This species is represented by a single specimen observed in my collection. Its reference to *Granulati-sporites* may be questioned because of the flattened nature of the pyramic area which is unlike other described species of this genus. The lack of material prevents possible assignment to a new genus at this time. *Granulati-sporites* sp. B. resembles Raistrick and Simpson's (1933, p. 228, fig. 1) spore type D_4 which has the same type of ornamentation. Illustrations of this type indicate a flat pyramic area.

Occurrence.—Post-Madison, pre-Belden coal of Daggett County, Utah.

Genus LAEVIGATO-SPORITES
(Ibrahim) Schopf, Wilson and Bentall

Laevigato-sporites IBRAHIM 1933, Sporenformen des Aegirhorizonts, p. 39.—emend. SCHOPF, WILSON and BENTALL, 1944, Illinois Geol. Survey Rept. Inv. 91, pp. 36–37.

Genotype.—*Laevigato-sporites vulgaris* (Ibrahim) Ibrahim, by designation of Ibrahim, 1933, p. 39.

LAEVIGATO-SPORITES sp. A
Plate 40, figure 1

Description.—Spore monolete, bilateral; elongate oval in plane of longitudinal symmetry; length, 55 microns, width, 35 microns; surface of spore saetose to spinose, spines 2 to 3 microns long, 2 to 3 microns wide at the base, equilateral in outline; monolete suture 45 microns long.

Remarks.—This species is represented by a single specimen observed in my collection. Its ornamentation is similar to that of specimens of *Granulati-sporites* cf. *G. microsaetosus* (Loose) Schopf, Wilson, and Bentall, 1944, observed in my collection.

Occurrence.—Post-Madison, pre-Belden coal of Daggett County, Utah.

Genus DENSO-SPORITES (Berry) Schopf, Wilson and Bentall

Denso-sporites BERRY, 1937, Amer. Midland Naturalist, vol. 18, no. 1, p. 157.—emend. SCHOPF, WILSON and BENTALL, Illinois Geol. Survey Rept. Inv. 91, pp. 39–40.

Genotype.—Denso-sporites covensis Berry, by designation of Berry, 1937, p. 157.

DENSO-SPORITES DAGGETTENSIS Schemel, n. sp. Plate 39, figures 16, 17

Description.—Spores trilete, radial; subtriangular in transverse plane; total diameter 33 to 50 microns; proximal and distal portions of wall thin and membranous, equatorial portions of wall thickened, equatorial thickening 5 to 9 microns wide, spore cavity 21 to 32 microns in diameter, equatorial thickening overlaps edge line of spore cavity, which is broken at one or more of its angles; surface of spore slightly punctate; presence of trilete inferred from triangular shape of the spore cavity and breaks at boundary angles.

Remarks.—The holotype (fig. 16) shows a fine crack leaving a break in the spore cavity. This break is not usually present in other specimens of this species. *Denso-sporites densus* Berry, 1937, is somewhat larger than *Denso-sporites daggettensis* n. sp., and the spore cavity of Berry's species appears smaller than that of this new species.

Occurrence.—Post-Madison, pre-Belden coal of Daggett County, Utah.

DENSO-SPORITES DOMINATORIS Schemel, n. sp. Plate 40, figure 2

Description.—Spores trilete, radial; circular to subtriangular in transverse plane; total diameter 30 to 45 microns; proximal and distal portions of wall thin and membranous, equatorial portion of wall thickened, equatorial thickening 8 to 12 microns wide, spore cavity triangular, 18 to 24 microns in diameter, equatorial thickening overlaps edge line of spore cavity and is constricted at angles where edge line is broken and flared outward; surface of spore cavity slightly granulose, equatorial portions characteristically rugose; presence of trilete suture inferred from triangular shape of the spore cavity and the three breaks of the edge line.

Remarks.—The holotype is one of the few specimens that has the thin walls of the spore cavity preserved. This species differs from *Denso-sporites daggettensis* n. sp. in that it is more circular in outline, the equatorial thickening is wider in proportion to the total diameter, and the edge line flares outward at each angle of the triangular spore cavity. It resembles Raistrick and Simpson's (1933, p. 227, fig. 1) spore type A_1, which has similar general characteristics. The flaring of the edge line was not noted by Raistrick and Simpson in their discussion of the British forms.

Occurrence.—Post-Madison, pre-Belden coal of Daggett County, Utah.

Genus ENDOSPORITES Wilson and Coe

Endosporites WILSON and COE, 1940, Amer. Midland Naturalist, vol. 23, no. 1, p. 184.

Genotype.—Endosporites ornatus Wilson and Coe, by designation of Schopf, Wilson and Bentall, 1944, p. 45.

ENDOSPORITES PALLIDUS Schemel, n. sp. Plate 40, figure 3

Description.—Spores trilete, radial; circular to subcircular in transverse plane; total diameter 54 to 66 microns, central body diameter 33 to 50 microns; surface of bladder minutely granulose to weakly punctate, relief of ornamentation less than 0.4 micron, ornamentation of central body obscured; central body wall approximately 0.5 micron thick, bladder wall somewhat thinner; trilete rays one-half to two-thirds the length of the central body radius, very poorly developed and usually not observed, lips not modified.

Remarks.—The holotype is one of the few specimens observed which possesses a definite trilete suture. This species is similar to *Zonotriletes marginatus* Luber, 1938, in that the ratio of the diameter of the bladder to that of the central body is approximately the same but detailed information concerning Luber's species is lacking. *Endosporites pallidus*, n. sp. does not possess the internal fine meshed reticulation pattern, a character

commonly present in Pennsylvanian species of the genus.

Occurrence.—Post-Madison, pre-Belden coal of Daggett County, Utah.

ENDOSPORITES sp. A
Plate 40, figure 4

Description.—Spore trilete, radial; central body and bladder subtriangular in transverse plane; total diameter approximately 65 microns, central body diameter approximately 35 microns; surface of bladder granulose with indication of reticulation; ornamentation of central body obscured; central body wall slightly thicker than that of bladder; trilete rays extend to the periphery of central body and thickened continuations from them extend on to bladder membrane; trilete rays 1 to 6 microns shorter than the length of the total radius.

Remarks.—This species is similar to *Endosporites rarus* (Ibrahim) Schopf, Wilson, and Bentall, 1944, although the latter is much smaller. Both species possess thickened continuations of the trilete rays on the bladder membrane.

Occurrence.—Post-Madison, pre-Belden coal of Daggett County, Utah.

ENDOSPORITES sp. B
Plate 40, figure 5

Description.—Spores trilete, radial; subtriangular in transverse plane; total diameter approximately 62 microns, central body diameter approximately 35 microns; surface of bladder minutely granulose with slight reticulation; ornamentation of central body obscured; central body wall much thicker than bladder wall; trilete rays approximately 5 microns shorter than the length of the radius of the central body.

Remarks.—This species is similar to *Endosporites rotundus* (Ibrahim) Schopf, Wilson, and Bentall, 1944, although the latter is larger and possesses trilete rays which extend to the edge of the central body.

Occurrence.—Post-Madison, pre-Belden coal of Daggett County, Utah.

Genus LYCOSPORA Schopf, Wilson and Bentall

Lycospora SCHOPF, WILSON and BENTALL, 1944, Illinois Geol. Survey Rept. Inv. 91, p. 54.

Genotype.—*Lycospora micropapillatus* (Wilson and Coe) Schopf, Wilson and Bentall, by designation of Schopf, Wilson and Bentall, 1944, p. 54.

LYCOSPORA sp. A
Plate 40, figure 6

Description.—Spores trilete, radial; circular in transverse plane; diameter 29 to 33 microns; surface of spore weakly punctate to weakly granulate; equatorial ridge 2 to 5 microns wide; trilete rays extend to ridge, lips well defined, approximately 2 microns thick.

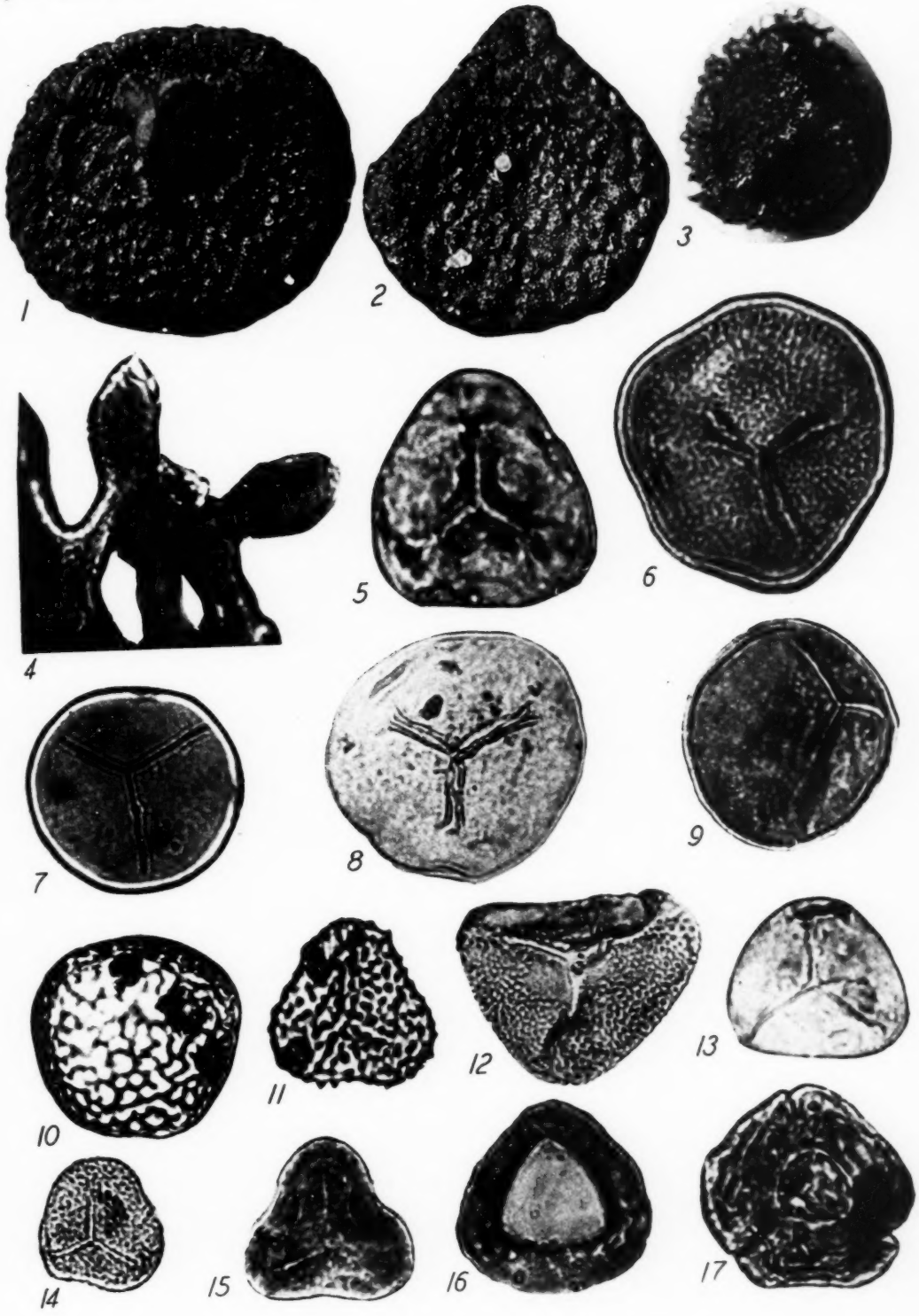
Remarks.—This species may be related to *Lycospora pusillus* (Ibrahim) Schopf, Wilson, and Bentall, 1944, but the brevity of Ibrahim's description and the generalized nature of the spores themselves makes it impossible to state that they could be conspecific.

Occurrence.—Post-Madison, pre-Belden coal of Daggett County, Utah.

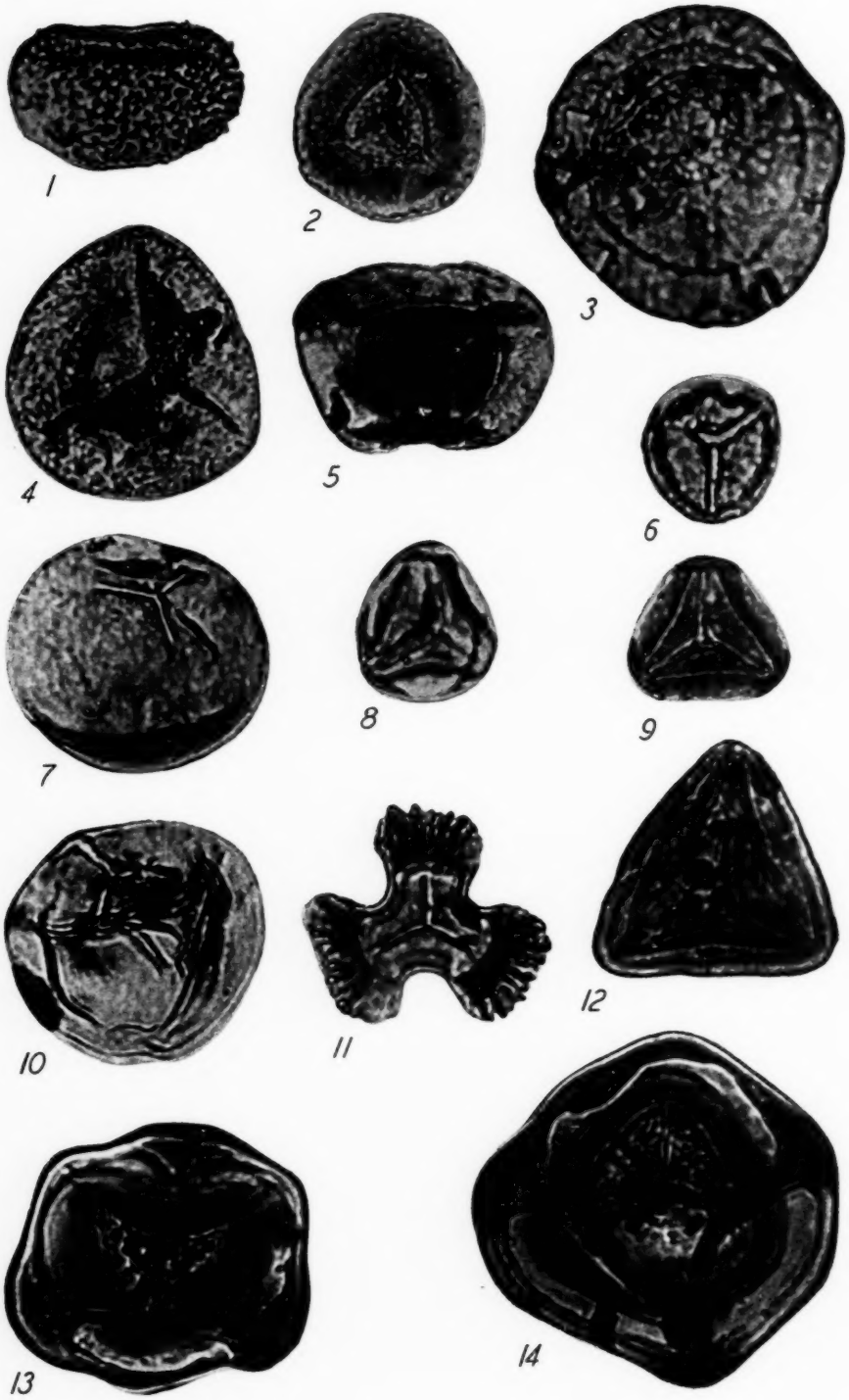
EXPLANATION OF PLATE 39

All figures ×550, except *1–3*.

FIGS *1, 2*—*Triletes agnina* (Zerndt) Schopf, Wilson and Bentall, 1944, ×40. (p. 235)
3, 4—*Triletes* cf. *T. radiosus* Schopf, Wilson and Bentall, 1944. *3*, ×40; *4*, detail of equatorial flange. (p. 235)
5—*Punctati-sporites* sp. A. (p. 236)
6—*Punctati-sporites utahensis* Schemel, n. sp.; holotype. (p. 236)
7—*Punctati-sporites* sp. B. (p. 236)
8—*Punctati-sporites* sp. C. (p. 236)
9—*Punctati-sporites* sp. D. (p. 236)
10—*Punctati-sporites* sp. E. (p. 237)
11—*Granulati-sporites* cf. *G. microsaetosus* (Loose) Schopf, Wilson and Bentall, 1944. (p. 237)
12—*Granulati-sporites* sp. A. (p. 238)
13—*Granulati-sporites inflatus* Schemel, n. sp; holotype. (p. 238)
14—*Granulati-sporites* cf. *G. granulatus* Ibrahim, 1933. (p. 237)
15—*Granulati-sporites* sp. B. (p. 238)
16, 17—*Denso-sporites daggettensis* Schemel, n. sp. *16*, Holotype; *17*, tetrad. (p. 239)



Schemel, Utah Carboniferous plant spores



Schemel, Utah Carboniferous plant spores

Genus CALAMOSPORA Schopf, Wilson and Bentall

Calamospora SCHOPF, WILSON and BENTALL, 1944, Illinois Geol. Survey Rept. Inv. 91, pp. 49–52.

Genotype.—*Calamospora hartungiana* Schopf, in Schopf, Wilson and Bentall, by designation of Schopf, Wilson and Bentall, 1944, p. 51.

CALAMOSPORA cf. C. MICRORUGOSUS (Ibrahim) Schopf, Wilson and Bentall
Plate 40, figure 10

Sporonites microrugosus IBRAHIM, 1932, Neues Jahrb., Beilage-Band 67, Abt. B, p. 447, pl. 14, fig. 9.
Laevigati-sporites microrugosus (IBRAHIM) IBRAHIM, 1933, Sporenformen des Aegirhorizonts, p. 18, pl. 1, fig. 9.
Calamospora microrugosus (IBRAHIM) SCHOPF, WILSON and BENTALL, 1944, Illinois Geol. Surv. Rept. Inv. 91, p. 52.

Description.—Spores trilete, radial; subcircular in transverse plane; folds frequent and taper-pointed with lenticular outline; diameter 56 to 86 microns; surface of spore laevigate; trilete rays very slightly sinuous, approximately two-thirds the length of the radius, lips not modified.

Remarks.—Ibrahim's original description gave only one size measurement, 96 microns in diameter, but his later description gave a diameter range from 58 to 96 microns. The largest specimen observed in my collection is 86 microns in diameter.

Occurrence.—Coals of the Westphalian B zone of the Ruhr district of western Germany; post-Madison, pre-Belden coal of Daggett County, Utah.

CALAMOSPORA cf. C. PALLIDUS (Loose) Schopf, Wilson and Bentall
Plate 40, figure 7

Sporonites pallidus LOOSE, 1932, Neues Jahrb., Beilage-Band 67, Abt. B, p. 449, pl. 18, fig. 31.
Punctati-sporites pallidus (LOOSE) IBRAHIM, 1933, Sporenformen des Aegirhorizonts, p. 21; LOOSE, 1934, Inst. Paläobot. Arb., vol. 4, no. 3, p. 146.
Calamospora pallidus (LOOSE) SCHOPF, WILSON and BENTALL, 1944, Illinois Geol. Survey Rept. Inv. 91, p. 52.

Description.—Spore trilete, radial, subcircular in transverse plane; folds frequent and taper-pointed with lenticular outlines; approximately 62 microns in diameter; surface of spore very weakly punctate; trilete rays 12 to 16 microns long, lips not prominent.

Remarks.—This species is represented by a single specimen observed in my collection. It checks well with Loose's original and later descriptions, but I hesitate to make a definite assignment without more specimens.

Occurrence.—Coals of the Westphalian B zone of the Ruhr district of Western Germany; post-Madison, pre-Belden coal of Daggett County, Utah.

Genus ROTASPORA Schemel, n. gen.
Text figure 2

Genotype.—*Rotaspora fracta* Schemel, n. sp.

Description.—Spores trilete, radial; circular to subcircular in transverse plane; central body subequilaterally triangular in transverse plane with rounded corners and convex or concave sides; forms now known

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EXPLANATION OF PLATE 40

All figures ×550.

FIGS. *1*—*Laevigato-sporites* sp. A. (p. 238)
2—*Denso-sporites dominatoris* Schemel, n. sp.; holotype. (p. 239)
3—*Endosporites pallidus* Schemel, n. sp.; holotype. (p. 239)
4—*Endosporites* sp. A. (p. 240)
5—*Endosporites* sp. B. (p. 240)
6—*Lycospora* sp. A. (p. 240)
7—*Calamospora* cf. *C. pallidus* (Loose) Schopf, Wilson and Bentall, 1944. (p. 241)
8, 9—*Rotaspora fracta* Schemel, n. sp. *8*, Holotype; *9*, typical specimen. (p. 242)
10—*Calamospora* cf. *C. microrugosus* (Ibrahim) Schopf, Wilson and Bentall, 1944. (p. 241)
11—*Tripartites vetustus* Schemel, n. sp.; holotype. (p. 243)
12—Spore type A. (p. 243)
13, 14—Spore type B. (p. 244)

range from 28 to 46 microns in diameter; spore coat relatively thin; surface of central body and flange laevigate, punctate, granulose, or verrucose, both do not necessarily possess same ornamentation; equatorial flange broadest at interradial regions and very narrow on the corners, flange thickened at periphery to form a narrow rim; trilete rays slightly shorter than the radius; trilete lips not modified; affinities unknown, possibly filicinean, perhaps related to *Reinschospora* Schopf, Wilson, and Bentall.

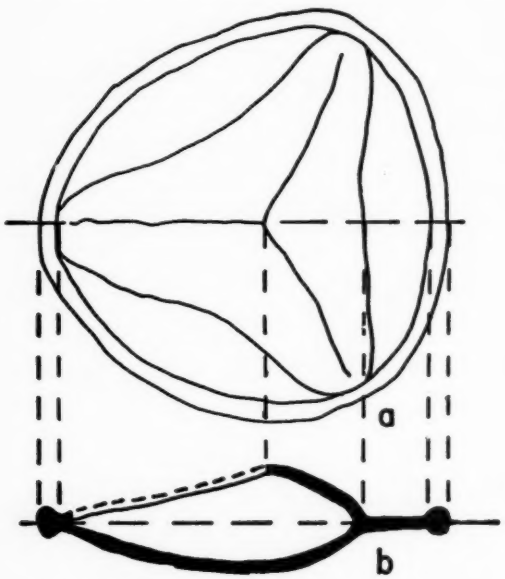

FIG. 2—*Rotaspora* Schemel, n. gen.; *a*, equatorial (transverse) plan; *b*, axial (longitudinal) plan.

Remarks.—This genus appears to include one of the forms Reinsch (1884, vol. 1, p. 16, diag. 88, pl. 6, fig. 75) described as his Subdivisio VII of his Subtribus I, *Nucleus triangularis*. This spore type was listed by Reinsch from the "Stigmarienkohle" of central Russia.

ROTASPORA FRACTA Schemel, n. sp.
Plate 40, figures 8, 9

Description.—Spores trilete, radial; circular to subcircular in transverse plane, central body subequilaterally triangular in transverse plane, corners rounded, sides straight to slightly concave; total diameter 28 to 35 microns, central body diameter 17 to 24 microns; equatorial flange broadest at interradial regions and very narrow on the corners, flange thickened at periphery to form a rim approximately 2 microns wide; surface of spore laevigate to minutely punctate, no differentiation of ornamentation between central body and flange; trilete rays 1 to 2 microns shorter than the length of the radius, lips not modified.

Remarks.—The holotype (fig. 8) is one of the few specimens observed in my collection with peripheral rim well preserved. Most of the specimens are broken at interradial areas.

Occurrence.—Post-Madison, pre-Belden coal of Daggett County, Utah.

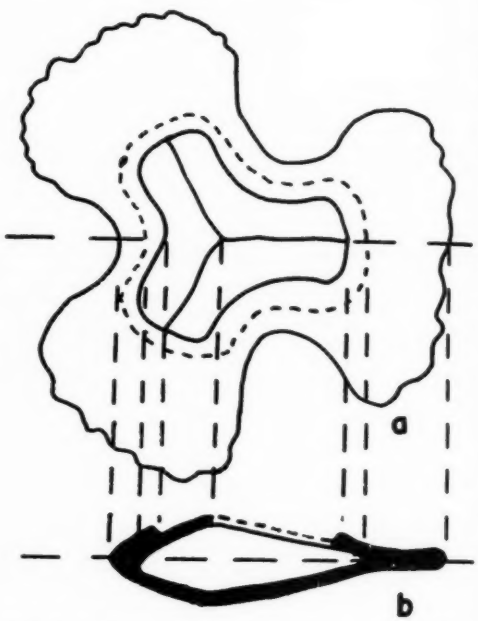

FIG. 3—*Tripartites* Schemel, n. gen.; *a*, equatorial (transverse) plan; *b*, axial (longitudinal) plan.

Genus TRIPARTITES Schemel, n. gen.
Text figure 3

Genotype.—*Tripartites vetustus* Schemel, n. sp.

Description.—Spores trilete, radial; central body subtriangular in transverse plane, corners rounded or blunt, sides convex, straight, or concave; equator marked by

equatorial flange (or analogous structure) which is widest at corners and very narrow or absent in the interradial regions, usually plicated in widest portions; forms now known range from about 30 to over 70 microns in diameter; central body and flange laevigate, punctate, granulose, or verrucose, both do not necessarily possess same ornamentation; trilete rays usually well defined and extend to margin of central body but not onto flange, moderate lips may be developed; affinities unknown, possibly filicinean, perhaps related to *Triquitrites* Wilson and Coe.

Remarks.—This genus appears to include the spores Reinsch (1884, vol. 1, p. 35) designated as his Subdivisio XLVI of his Subtribus I, *Nucleus triangularis*. His description is as follows: "Exosporium inaequaliter triangulatim incrassatum, angulis productis, obtusatis et crenulato-incisis." These forms described by Reinsch were structurally clarified by Luber and Waltz (1938) by their publication of a species, *Zonotriletes inciso-trilobus* (Naumova) Waltz, 1938, listing one of Reinsch's forms in synonomy. This species was described by Naumova in a manuscript, and Luber and Waltz (1938) credit Waltz for a new specific combination of this species. This paper by Luber and Waltz is the first publication of Naumova's species. Naumova (1934, pl. 3, fig. 9) had earlier illustrated this form but did not describe or name it. This species is apparently congeneric with *Tripartites vetustus* n. sp. Difficulties regarding the status and type species of *Zonotriletes* prevent any new assignment at this time. Raistrick (1934, p. 145, pl. 1) described and illustrated a spore type, D_7, which appears to be included in *Tripartites*. This type was further described and illustrated by Raistrick (1938) and Knox (1947).

TRIPARTITES VETUSTUS Schemel, n. sp.
Plate 40, figure 11

Description.—Spores trilete, radial; subtriangular in transverse plane, corners broadly rounded or blunt, sides moderately to strongly concave; equator marked by equatorial flange (or analogous structure) which is widest at the corners and very narrow or absent in the interradial regions, plicated in the widest portions; total diameter 30 to 40 microns, central body diameter 19 to 25 microns; extended portions of flange outline approximately 10 by 15 microns; surface of central body laevigate to minutely punctate, surface of flange laevigate; trilete rays 1 to 2 microns shorter than the length of the radius.

Remarks.—Most specimens are poorly preserved in that the central body has been badly corroded. The holotype illustrates the average concavity of the sides.

Occurrence.—Post-Madison, pre-Belden coal of Daggett County, Utah.

INCERTAE SEDIS

The two forms listed below are placed under *incertae sedis* because they are lacking in sufficiently understood biological characteristics to support definite systematic allocations. They are represented by very few specimens observed in my collection and more material is necessary to confirm their morphology. They do not show convincing evidence of affinity with other recognized groups and they thus may represent new genera. They are included because of their unusual nature which may prove to be significant in age determinations should similar forms be recognized in other collections.

SPORE TYPE A
Plate 40, figure 12

Description.—Spore trilete, radial; triangular in transverse plane; corners rounded, sides straight to slightly convex; diameter approximately 56 microns; surface of spore laevigate to minutely punctate; spore wall relatively thick; equatorial flange (?) surrounding triangular central area; flange thickened about periphery to form peripheral rim (?) approximately 5 microns wide; apparent thickening of spore walls in interradial areas probably due to folding of the pyramic segments; trilete suture broken but rays appear to be at least two-thirds the length of the radius.

Remarks.—This form is represented by a single specimen observed in my collection. Certain features of this spore might warrant its inclusion in *Rotaspora*, n. gen., but it is excluded because the structures cannot be interpreted with any degree of certainty at this time. This form is somewhat similar to the form Reinsch (1884, vol. 1, p. 16, diag.

154, pl. 18, fig. 118C) listed from the Zwickau coal of Saxony under his Subdivisio XIII of Subtribus I, *Nucleus triangularis*.

Occurrence.—Post-Madison, pre-Belden coal of Daggett County, Utah.

SPORE TYPE B
Plate 40, figures 13, 14

Description.—Spores trilete, radial; subcircular in transverse plane; total diameter approximately 75 microns; spore apparently consisting of two units, a central body and a structure perhaps analogous to an equatorial flange; central body 30 to 35 microns in diameter, equatorial flange (?) approximately 20 microns in diameter with a peripheral rim (?) approximately 5 to 7 microns wide in radial areas and broadened to form "pads" approximately 15 microns wide in the interradial areas; peripheral pads interconnected by bands approximately 6 microns wide which cross over the central body; central body slightly papillate, remainder of spore laevigate; trilete rays extend to the borders of the central body, lips not modified.

Occurrence.—Post-Madison, pre-Belden coal of Daggett County, Utah.

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JOURNAL OF PALEONTOLOGY, VOL. 24, NO. 2, PP. 245–247, MARCH 1950

REVIEWS

SMALLER FORAMINIFERA FROM BODJONEGORO (JAVA), by L. Boomgaart. Thesis, State University of Utrecht (Netherlands), Smit & Dantje, Sappemeer, 1949. Pp. 1–175, pls. 3, figs. 7, tables 1.

This thesis is another important contribution to knowledge of the smaller Foraminifera from the Indonesian Mio-Pliocene. It is a worthy supplement to the papers of LeRoy (1939, 1941 and 1944) and several others of less importance. The author describes the smaller Foraminifera from 81 core samples of an exploratory well 2006 meters deep in the Mio-Pliocene at Bodjonegoro (Java-Indonesia) drilled in 1934. Two hundred and ninety-two species are described or mentioned, representing 24 families, 89 known genera and one new genus. A total of 30 species and ten varieties are described as new. Seventy forms are unnamed.

The new genus *Pseudonodosaria* of the family Lagenidae is closely related to *Pseudoglandulina* and most of its species hitherto have probably been considered *Pseudoglandulinae*. Its early part is as *Pseudoglandulina*, with embracing uniserial chambers; the adult stage is definitely nodosarian. The genotype is *Glandulina discreta* Reuss 1850.

Most of the previously known species are not redescribed although remarks concerning some of them are presented. Many of them, however, are figured. The descriptions of new species are clear, but differential discussions are mostly lacking and thus comparison with related species is rather difficult. The illustrations are excellent shaded camera-lucida drawings, partly drawn by the famous artist of the Netherlands Geological Survey, J. Lammers.

In a general part of the report the author discusses several aspects of previous work on Indonesian smaller Foraminifera. He presents remarks on the stratigraphic section and environmental condition of deposition and concludes that the faunae are of bathyal origin.

An appendix gives some details about the otoliths, examined by F. C. Stinton.

The Ostracoda from this well have been studied by Dr. J. Th. Kingma (1948).

A. TEN DAM

CONTRIBUTIONS TO THE KNOWLEDGE OF THE YOUNG CAENOZOIC OSTRACODA FROM THE MALAYAN REGION, by J. Th. Kingma. Thesis, State University of Utrecht (Netherlands); Kemink N. V., Utrecht, 1948. Pp. 1–118, pls. 11, figs. 3, tables 8, 1 distribution chart.

As only a very small number of fossil Ostracoda have been described from Indonesia this thesis is a most valuable contribution. Dr. Kingma studied specimens from the following localities: Mio-Pliocene of Atjeh (North Sumatra) and of the Bodjonegoro well (East Java), Pliocene of the southern Kendeng area (East Java) and bottom samples of Recent material from three stations in the Java Sea, collected by the Snellius expedition.

The paper begins with a chapter on the hinge patterns of the principal Cenozoic ostracode genera, as the author believes them to be the most important features for classifying these fossils. This compilation will serve as a key for beginners, supplementing Dr. van den Bold's useful paper. The hinge patterns are figured in a series of clear pen and ink drawings on five plates.

The second part of the paper deals with the stratigraphic distribution of the samples and with the systematic description of 94 species and four varieties which are figured by pen and ink drawings on six plates. Six new genera are described: *Hemicytheridea* (family Cytheridae, subfamily Cytherideinae), *Atjehella* (family Cytheridae, subfamily Cytherinae), *Payenborchella* (family Cytheridae, subfamily Cytherinae), *Tanella* (family Cytheridae, subfamily Cytherinae), *Javanella* (family Cytheridae, subfamily Cytherinae) and *Neomonoceratina* (family Cytheridae, subfamily Bythocytherinae).

A. TEN DAM

FORAMINIFÈRES D'AQUITAINE PREMIÈRE PARTIE: REOPHACIDAE À NONIONINIDAE), by J. Cuvillier and V. Szakall. Imprimerie F. Boisseau, Toulouse, France, 1949. Pp. 1–112, pls. 32; 1800 francs.

This publication was prepared at the Stratigraphical Laboratory of the Société Nationale des Pétroles d'Aquitaine and published under the auspices of this company. It is the first part of what the authors call a Monograph of the Foraminifera from Aquitania, and deals with 518 species from the families Reophacidae to Nonioninidae obtained from formations of Triassic to Pliocene age. Fourteen species and one genus are described as new and 136 forms have not been named. The most valuable part is the 32 plates where all species are figured in shaded photographs of reasonable and often good quality. The stratigraphic distribution of the species is mentioned in the text.

The authors purposely give no detailed descriptions of already known species except when it is necessary to mention particular characters. In a second part they will present the remaining species and a general consideration on the microfaunal associations and their application to stratigraphic and geological problems.

The species determinations are inadequate and evidently they are based on far too little documentation, so that numerous nomenclatural errors occur. References to recent publications, like those of Colom, Cushman and numerous other authors between 1942 and 1949 are almost entirely lacking and much of the older literature also has not been consulted. The authors do not differentiate *Textularia* and *Spiroplectammina*—*Textularia carinata d'Orbingy* and *T. adamsi* (Lalicker) are without doubt typical representatives of *Spiroplectammina* but they are classified under *Textularia*. One species described as *T. annectens* Parker and Jones seems to be a *Textularia* according to the figures whereas the true *T. annectens* from the Lower Cretaceous has a triserial initial stage, biserial young and uniserial adult, and is the genotype of *Spiroplectinata*, erected by Cushman in 1927. Descriptions of new species are often quite insufficient and differential diagnoses are mostly lacking. Their *Spiroloculina eocenica* belongs to *Sigmoilina*, as is evident if Cushman's monographs on these two genera are consulted. It seems probable from their figures that the new species *Nodobaculariella tubiformis* is only the adult stage of their *Articulina oligocenica*, n. sp., from the same locality. Several species of *Articulina* show an irregular terminal chamber tending to become uniserial, similar to the last chamber in "*Nodobaculariella*" *tubiformis* n. sp. The young and adult stages of their *Articulina oligocenica* seem very closely related, if not identical with, *Articulina advena* (Cushman) 1922, also from the Oligocene, as figured and described in Cushman's Monograph on *Articulina* of 1944. The figures of *Robulus degolyeri* do not correspond with the original figures nor with topotypes in my collection from the Midway (Plummer, 1926). *Robulus cuvillieri* Texier 1944 is identical with *Hydromylina rutteni* de Witt Puyt 1941 from the Middle Eocene of Dalmatia. Their *Flabellina arborescens* (Halkyard), with typical pustular ornamentation, has no characters in common with the original reticulated *Frondicularia arborescens* Halkyard 1918 which is a typical *Coleites*. Several excellent representatives of the genus *Palmula* are included under the genus *Frondicularia*. The foregoing are some of the taxonomical shortcomings of this work.

The new genus *Daxia* of the family Lituolidae is closely related to and intermediate between *Haplophragmoides* and *Cyclammina*. It has a planispirally coiled, bilaterally symmetrical, involute test. The inner structure resembles *Nummulites*. The wall is finely arenaceous and chambers are numerous. Its genotype is *D. cenomana* n. sp. and it is known only from the Cenomanian.

It is unfortunate that the authors of this atlas have not paid more attention to correct taxonomy and nomenclature because their figures and data on stratigraphic distribution might be very useful to micropaleontologists and geologists working in the Mediterranean region. As it is, comparison with well known Mediterranean microfaunae like those from the Burdigalian and Vindobonian of the Balearics by Colom is extremely difficult. This work will be valuable for internal use in Aquitania in the application of micropaleontology to strati-

graphic and geologic problems, but it has little value outside of that region where workers have applied nomenclatural principles more rigorously.

A. TEN DAM

THE MEANING OF EVOLUTION, A STUDY OF THE HISTORY OF LIFE AND OF ITS SIGNIFICANCE FOR MEN, by George Gaylord Simpson. 364 pp., Yale University Press, 1949. $2.75.

This book by one of America's foremost vertebrate paleontologists is an expansion of a series of lectures given at Yale University in 1948 under the sponsorship of the Terry Foundation in the general field of "religion in the light of science and philosophy." It is primarily interesting as a philosophical work, and presentation of scientific facts, interpretations and theories is made as necessary background in a simplified and nontechnical manner. It consists of three approximately equal parts.

Part 1, *The Course of Evolution*, is mainly fact and interpretation. It contains nothing that is not fairly well known to every paleontologist and most geologists.

Part 2, *The Interpretation of Evolution*, is mainly interpretation and theory. Much of it is an extreme condensation of material more fully treated in some of the author's other writings, principally his *Tempo and Mode in Evolution*. It is concluded, however, with chapters on the concept of progress in evolution and the history of evolutionary thought. The former is strictly philosophical and belongs in the last section of the book. The latter is an excellent summary of 17 pages and contains more well coordinated information on this subject than any comparable presentation that I know.

Part 3, *Evolution, Humanity, and Ethics*, is the heart of the book. It is entirely philosophical and subject to all the criticisms that apply to reasoning of this kind. Simpson is unquestionably a thoughtful scientist of broad interests and his ideas should be of interest to many other thoughtful persons even if they are unable to subscribe to them.

Like most philosophies, Simpson's is founded on certain interpretations that are accepted as facts, and proceeds to certain preconceived ideas. This is done by means of the development of a system of ethics which evidently, for him, takes the place of formalized religion. It happens that I agree with his premise that natural processes are entirely materialistic, that evolution has been purposeless and opportunistic and that man is an animal similar in most of his attributes to other animals. I also share his preconceived ideas which focus upon the ideal of perfect democracy. Finally I sympathize with his ethics which, in essence, measure the greatest good in terms of the accumulation and dissemination of knowledge, although I cannot believe that this is the end of all ends to be desired.

Like most philosophers, Simpson has his feet on two different spheres rotating at different speeds in different planes. His efforts to bridge this gap between the sphere of scientific fact and the sphere of moralistic ideals appear to me somewhat forced and in part inconsistent. For example, he emphatically denies that human society, composed of interdependent individuals, is at all comparable to an organism, composed of interdependent cells, but he places great emphasis on human extra-material "evolution" which can only be a phase of social progress, measured by Simpson in terms of experience past and present mutually shared through the spoken or written word, to which individuals respond as a factor of their environment. Probably because he feels so strongly, repetition and reiterative emphasis make this part of the book too long.

The first two parts of the book can be highly recommended to any serious nonbiologist who desires a quick but authoritative survey of evolutionary facts and theories. It encompasses a vast and ever expanding field of knowledge in which most biologists and paleontologists are in essential agreement. The final part is interesting as one man's excursion into a highly subjective field where, since the beginning of history, philosophers have, in contrast, made practically no progress in agreement.

Some of the most pithy and enjoyable parts of the book are included in the numerous footnotes.

J. M. W.

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